IV. THE GEOLOGY OF PITTSBURGH AND ITS ENVIRONS: A POPULAR ACCOUNT OF THE GENERAL GEOLOGIC FEATURES OF THE REGION.

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(Plates I–VII)

Introductory.

The interest in outdoor pursuits seems to be increasing. The hiking clubs, the Audubon Societies, the Boy Scout movement are all indications that we city people feel the need of health conservation and link with it outdoor hobbies or pleasures, which stimulate our imagination and develop in us greater love for the things of nature. It may be an interest in botanical specimens, shells, or insects, in birds, in reptiles, or in mammals, which calls us out; or it may be that some of us desire a better acquaintance with the rocks and their most interesting history. It is for the latter group that this paper has been written. Its purpose is to give in a simple way the story of the rocks of our district; a geological history, which may draw some into the open and arouse their curiosity sufficiently to take up the subject in greater detail and by their own observation add to our as yet meager knowledge of the geology of western Pennsylvania.

The literature concerning our local geology is at the best not voluminous, and is mainly scattered through government publications, some of recent date and some written at such an early date that the information they contain is not of great value. The present State Geological Survey at Harrisburg, under the able direction of Dr. George Ashley, is slowly and with scanty appropriations trying to study and publish upon the geology and the mineral resources of the State, and we hope that the geologic folio describing the Pittsburgh quadrangle may soon appear.

In the meanwhile it seems advisable to summarize and simplify such information as is at hand, adding to it many local details worked out by the geological department at the University of Pittsburgh, and publish it. This will then furnish a field manual for teacher, student, or nature-lover to use as a basis for study.

Plate I and fig. 7 are taken from the report of the Pennsylvania Geologic and Topographic Commission for 1906. The fossil animal remains shown on Plate II are copied from Bulletin 544 of the United States Geological Survey and Bulletin 17 of the Ohio State Geological Survey. The fossil plant remains shown on Plate VII, have been redrawn by Mr. Sydney Prentice from specimens figured by Lesquereux in the "Coal Flora Atlas" of the Second Geological Survey of Pennsylvania. Text figure No. 8 is a reproduction of a photograph of *Naosaurus* kindly given by the American Museum of Natural History. Grateful acknowledgment is made for permission to use all of these. The other figures and plates were drawn for or made from photographs by the author. To Mr. Sydney Prentice I wish to express my thanks for redrawing the sketches on which text-figures 1-6 are based. I cannot in concluding this paragraph fail to mention my sense of gratitude to Dr. W. J. Holland, the Editor, for numerous suggestions made by him which are embodied in the text and for the care given to the passage of the paper through the press.

CHAPTER I

Physiography of Pittsburgh

Standing upon any of the higher hills in Pittsburgh, such as Herron Hill, and looking out at the hilltops in all directions, one can not fail to be impressed with the uniform skyline or equal elevation of the high hilltops. It is evident that the whole region represents an ancient plateau, through which the large rivers and even their smaller tributaries have cut deep gashes. The hills are flat-topped and the stream-valleys are steep-sided. Such a region is called a dissected plateau, representing an elevated plain, over which streams have passed and through the long centuries have carved out their channels and formed tributaries in every direction, until now large or small streams penetrate almost the whole of the area, leaving only an occasional small flat-topped remnant of the plateau unattacked. These flat-topped hills lie at a uniform elevation of from twelve hundred to twelve hundred and sixty feet above sea-level, or a little more than five hundred feet above the level of the larger rivers. Occasionally an isolated hill rises above the general level to heights of thirteen hundred to fourteen hundred feet. During Cretaceous times the greater part of the Eastern United States is believed to have been reduced by the erosion of the rivers and the general process of erosion to a plain near sea-level, known as a peneplain, a base-levelled plain with a few remaining hills rising above the general level, which are called "monadnocks." This plain was later upraised, and the process repeated at different elevations, the result being that the Appalachian or Allegheny plateau is in reality a series of plateaus or peneplains. One of these, known as the Harrisburg plateau, or upland, lies now at about twelve hundred to thirteen hundred feet above sea-level in western Pennsylvania, rising to twenty-one hundred feet in southern New York. The accordant hill-tops already mentioned are believed to be remnants of this Harrisburg peneplain, and the occasional hills rising above the thirteen hundred foot level are to be classed as monadnocks. An example of such a hill would be the hill thirteen hundred and twenty feet high near the junction of the William Penn Highway and the Greensburg Pike.

Below the levels of the Harrisburg stage we find at about eleven hundred and twenty to eleven hundred and sixty feet above sea-level another series of "flats" which must represent another stage of erosion, or a period when the general plateau remained at a constant level and erosion and weathering reduced portions of its surface to this second level. A glance at your map will bring to light many remnants of this stage. This is known as the Worthington peneplain. The next well defined series of levels lies at from nine hundred to nine hundred and forty feet above the sea. These flat areas lie along or near the larger rivers, and represent valleys cut by the rivers flowing over the region at elevations about two hundred to two hundred and fifty feet above the present river-levels. These levels are hardly extensive enough to be regarded as representing peneplains, but rather as wide valleys cut to the nine hundred foot level by the rivers with their rock-cut bottoms covered with a deposit of sand, gravel, or clay deposited by the rivers. Such terraces are very conspicuous along the Ohio, Allegheny, Monongahela, and Youghiogheny rivers, as well as along some of their larger tributaries. On the Monongahela they are plainly seen at Clairton, forming the site of the city; at Kennywood Park; and in Upper Homestead. On the Allegheny River they can be seen at Verona back of Claremont, and on top of Monument Hill, North Side. On the Ohio the gravel-capped remnants of this terrace are numerous and can be seen at Avalon, Ben Avon, Emsworth, and further down the river as far as Freedom and beyond. This level has been called the Parker Strath, from its occurrence near Parkers Landing, and from an old Scottish word "strath" meaning a wide flat valley. The wide rivers flowed in valleys which in general followed the same courses as do the present rivers. The old elevated channels, when traced by means of the rock-terraces, are seen to cross and recross the present valleys, and at times to deviate from them in wide loops. These wide "straths," now no longer occupied by the major stream are extremely interesting traces of the older valleys. Their rock bottoms, as well as terraces, lie at about the nine hundred foot level and are covered with a blanket of from a few up to twenty-five feet of river silt, clay, and boulders. In Pittsburgh we have one of the best examples of such an abandoned river channel or loop (Fig. 1).

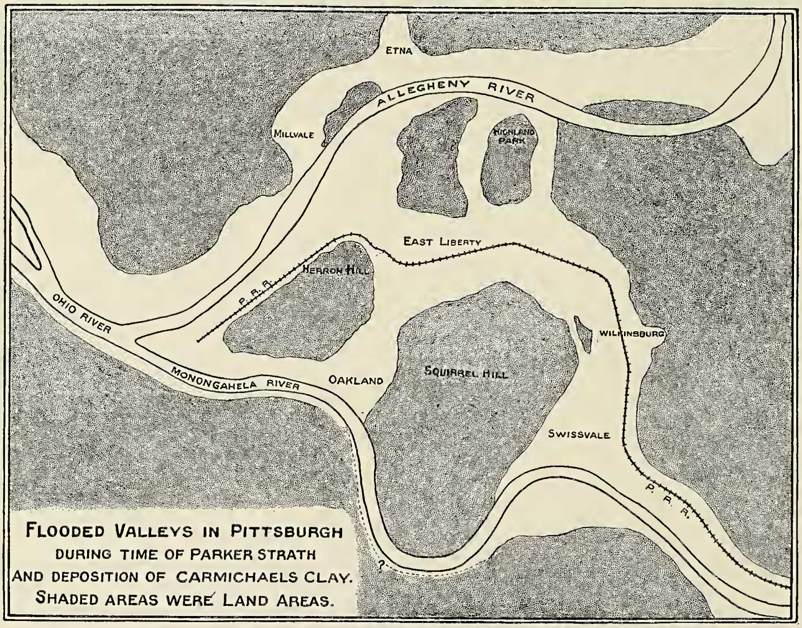

FIG. 1. Site of Pittsburgh at time of Parker Strath.
(The white spaces were areas covered by water).

This valley leaves the Monongahela valley on terraces in Rankin, passes across lower Edgewood, Wilkinsburg, East Liberty, swinging to the southwest past Herron Hill, and out to the edge of the Monongahela valley in Oakland. The Pennsylvania Railroad uses this wide flat valley from Rankin through East Liberty, and a glance at any topographic map will indicate by the number of streets in this valley how important a part it has had in the settlement of eastern Pittsburgh. Excavations made anywhere in this valley bring to light the layers of sand, clay, or boulders deposited by the river. The relation of this valley to low lying areas through Allegheny Cemetery, through the Morningside district, and through the Washington Boulevard area has not been established. Whether the Monongahela had outlets toward the Allegheny, whether it merely formed loops in those directions, or whether the elevated Allegheny entered these low "straths" and connected with the Monongahela, are problems to be solved.

The many excavations recently made in the East End for the larger buildings in the Schenley Farms district have furnished us with excellent cross sections of these old river deposits. The excavation for the Schenley apartments brought to light many feet of beautifully layered sands and clays evidently deposited in rather quiet ponded water. Similar deposits could be seen during the construction of the foundation for the Syria Mosque, the Young Mens Hebrew Association, as well as many excavations in Oakland, East Liberty, or Wilkinsburg. Often there are brought to light rounded boulders in abundance and throughout this old valley these are sometimes effectively used in building boulder walls or even boulder houses, as on Fifth Avenue near the corner of Wilkins. In many cases for the larger buildings it is necessary to penetrate from fifteen to fifty feet of such sands before striking the old rock bottom of the river on which the foundations can be safely placed. So far as has been noted, the sands and boulders of this old loop show no evidence of having been laid down by the Allegheny River; they are not glacial material, but are similar to the terrace-sands of the Monongahela River to the south.

A similar well developed river loop can be seen east of Belle Vernon, and a less well defined example back of McKeesport, the exact course of which has not been worked out. The sediments found in the abandoned valleys and on the rock terraces at this nine hundred foot level are of two distinct types. Those associated with the Monongahela River and its tributaries are generally fine yellowish sand and clay with some large water-worn boulders, all material evidently derived from the erosion of the sedimentary rocks in the drainage area. This material has been called the Carmichael formation. The sediments on the Allegheny River terraces consist of glacial sand and pebbles, gravels carried down from the ice-front of the Kansas epoch, which stood across the head-waters of the Allegheny valley, and which in melting discharged enormous amounts of such material brought down from New York State or Canada, and entirely distinct from the rocks native to our own region. These deposits will be discussed later in connection with the Glacial Period.

At intervals from the Parker levels down to present river-level, small and irregular rock-terraces are found covered with glacial gravels of Wisconsin age. About fifty to eighty feet above river-levels these gravels form well defined terraces representing the surface of a gravel-filled channel, which extends thirty to fifty feet beneath present river-level. In other words, the Ohio and Allegheny rivers, after carving their way through the Parker "strath" became again choked with gravel during the Wisconsin ice advance, this gravel building up on bed-rock a series of beds from one hundred to one hundred and fifty feet thick. The surface of this is still to be seen in the lower gravel-terraces along the rivers, and the present rivers have not yet succeeded in cutting through to old rock bottom. These later gravels appear in Neville Island to a depth of eighty feet, and extend forty or fifty feet below water-level. Many of the river cities are built on the gravel-terrace or upon a rock-cut gravel-covered terrace at about the same elevation. Summing up, we may say that the relief features of our city represent: (1) remnants of the Harrisburg peneplain twelve hundred and forty feet above sea-level; (2) remnants of the Worthington peneplain eleven hundred to eleven hundred and forty feet above sea-level; (3) terraces and abandoned channels of earlier rivers ("Parker strath") at nine hundred to nine hundred and forty feet above sea-level; (4) remnants of cut and built gravel-covered terraces at about seven hundred to eight hundred feet above sea-level; and (5) present streams with their flood-plains flowing over gravel-choked channels with low adjusted gradients and meandering channels.

CHAPTER II

HISTORICAL GEOLOGY

The rocks underlying the Greater Pittsburgh district have a wonderful history; a history, which, when interpreted by those trained to such work, is as real as is our own history. Is it not right that we always should have a reasonable curiosity concerning the forces which built up the land upon which we live?

If we were able to dig a well to almost unlimited depths anywhere in the city, we would find that we would be passing through layer upon layer of rock, laid down one upon the other in regular horizontal position. We would find that some layers were made up of grains of sand hardened into rocks which we call sandstone; some were made up of cemented pebbles or gravel (called conglomerate); some were soft and in very thin layers, often almost clay-like (called shale), and still others were hard and dense and with no apparent grain, the limestones. It is not likely that any other type of rock would be encountered throughout thousands of feet of digging, except an occasional thin layer of coal.

How, then, can we account for thousands of feet of such layers laid down in regular beds, first a sand-layer, then a clay or shale, then possibly a limestone? Certainly nothing but the sorting action of a large body of water could have separated them into such easily separable layers. Examination of some of the slabs of stone blasted out might even disclose ripple marks, mud cracks, impressions of rain-drops, and other evidences of the fact that the rocks were originally sand-beaches or mud-flats.

Careful search in the excavated material would also bring to light many curious forms of animal and plant life, which had once lived, and dying, had been entombed and are now preserved to us as fossils. Laying these remains out for study, we would find that, although the remains from one layer are very similar to those of the neighboring layers, there had been a gradual or progressive change in the character of the organisms as we pass through, say one thousand feet of strata. We would find many new forms at depths of ten thousand feet, forms entirely different from those near the surface. This means that the life in the past had changed as time went on, and animals, which existed when the older rocks were laid down, may not appear in the strata lying above.

To the experienced paleontologist, or student of these ancient forms of life, they tell a wonderful story, giving insight into the conditions which existed millions of years ago. They indicate to him the evolution of animals and plants from lower to higher and more complex forms. He sees types develop through a certain period and then decline. Any

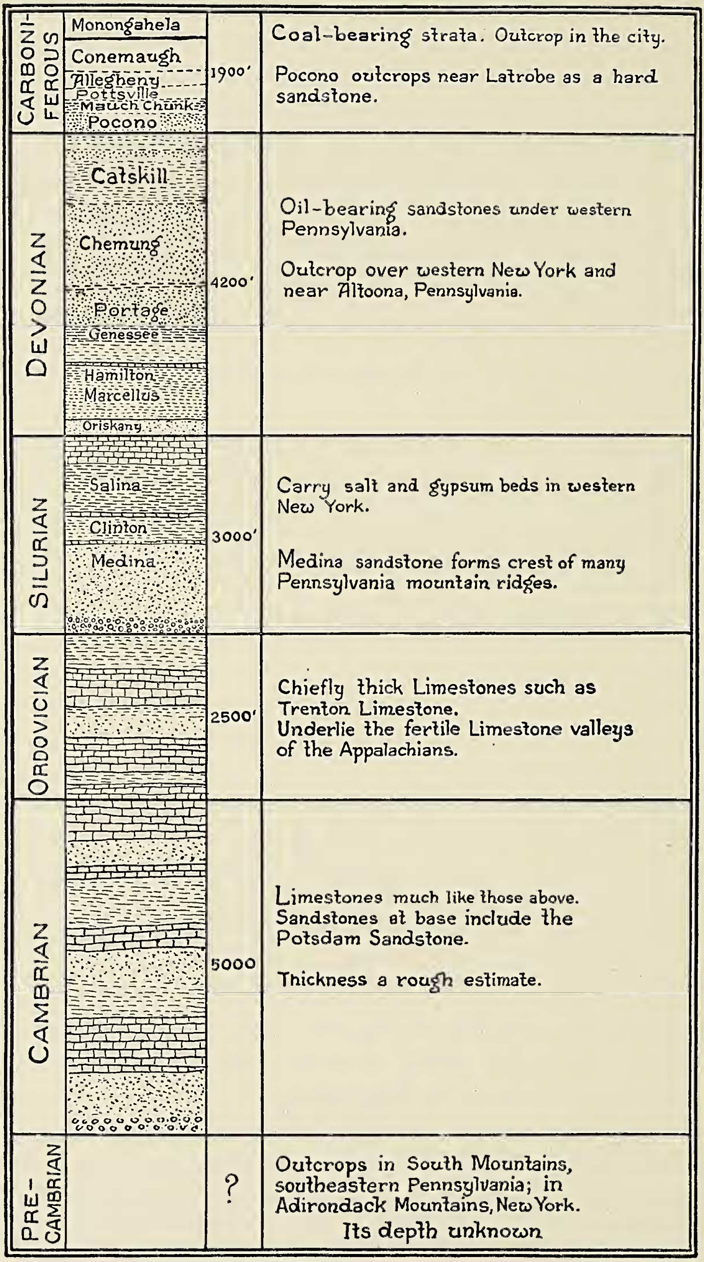

FIG. 2. The rocks under Pittsburgh.

particular group of animals and plants at a certain stage of development denotes to him a certain period, and these periods he has, for convenience, named. We study human history by a division into periods; we study geologic history in the same manner. Fossils are only illustrations on the pages of a marvelously planned book, the first pages of which lie at great depths in our region. To reach the earliest illustrated pages (with recognizable fossils) known as the Cambrian Period, our well would have to be sunk possibly ten thousand feet or more. Beneath the Cambrian, we would find a floor of rock of an entirely different character, rock which has undergone great heat, pressure, and re-crystallization, until its fossil remains, if it ever had any, have been obliterated. That portion of our history would correspond to our early human history, for we can do little better than speculate as to its life and its duration. Our finished well, if it were possible to sink such a shaft, would no doubt look something like the hypothetical sketch in Fig. 2.

Ah! but you say: "How does anyone know what lies ten thousand feet beneath his feet?" If our knowledge depended upon the sinking of wells or the drilling of holes to such depths, we would *not* know. But fortunately, nature has provided a more economical means of studying the older strata, and that is by tilting them up, so as to bring them to the surface at various points, so that they "outcrop," and these outcrops can then be studied. The cutting action of streams also exposes underlying layers even without tilting, as, for instance, the wonderful exposures in our own cliffs along the Monongahela River. Every deep stratum in our shaft, though seemingly horizontal, has some inclination or "dip," and at some point it reaches the surface and can be studied. We thus must take a brief glance at the geology and structure of the state as a whole before we can understand what has taken place in our own district.

We find that in the beginning of the Cambrian period the hard rock material, the history of which is so vague and which we call the pre-Cambrian complex, extended as a land mass over the most of northeastern Canada and in a narrow strip through New York, across southeastern Pennsylvania (in Adams, Berks, Chester, and neighboring counties) and on into Alabama. Westward hemmed in by land, north, east, and far to the west, was a wide inland sea, which, among other states, covered nearly all of Pennsylvania. Into this sea, from the highlands on the north and east, poured the drainage of streams laden with mud and sand. In it lived low forms of animal life, many of which, like the corals, had the power to secrete lime from the water of the ocean and, on dying, added their contribution to the sediments. In the same slow manner in which coast-lines are now built up through thousands of years, the beds of limestone, shale, and sandstone accumulated: first the Cambrian with its characteristic life-forms; then, overlapping and overlying it toward the center of the sea, the Ordovician; then in succession the Silurian; the Devonian; and the Carboniferous; made up of the Lower, or Mississippian, and the Upper, or Pennsylvanian systems. The building up of each consumed millions of years, giving ample time for great evolutionary changes in living things, and also for many oscillations in the level of the floor of the ocean, which probably was generally sinking, thus allowing for thick accumulations of sediment.

Near the end of the long time required to form the Pennsylvanian the basin had been almost filled, and we find the inland sea shrunken to a small shallow estuary opening toward the Gulf of Mexico; or, at times, a broad fluviatile flood-plain traversed by streams flowing toward the outlet in the direction of the Gulf. The conditions of these shallow flood-plains are clearly indicated in the rocks by the absence of limestone with a marine fauna, the presence of irregular "cross-bedding" in many of the sandstones, and the presence of widely spread coal-beds, which were originally peat-swamps of enormous extent, more or less covered by forests. The Pennsylvanian period ends the sedimentation of the basin. Readjustments in the earth's crust, earth-movements formerly ascribed to shrinkage of a cooling body, but more likely due to instability brought about by unequal loading, brought about a lateral pressure or thrust from the east. This caused the hitherto nearly horizontal sediments to buckle, and this buckling took place mainly in the eastern and central part of the state (Fig. 3b). On the Pennsylvania-Ohio border, we find the strata practically horizontal. As we pass east of Pittsburgh on the Pennsylvania, the Western Maryland, or the Baltimore and Ohio Railroads we begin to notice that certain layers rise and fall in long low swells. These swells become more and more pronounced, until the strata dip at a high angle and at times rise almost vertically along the cliffs, and railway cuttings. This folding and the truncation or planing away of the crests of many folds by subsequent erosion has brought to the surface many strata which ordinarily we would only see toward the old margin of the inland sea. Thus an upfold or anticline and subsequent erosion have exposed Mississippian and Devonian rocks on Chestnut Ridge.

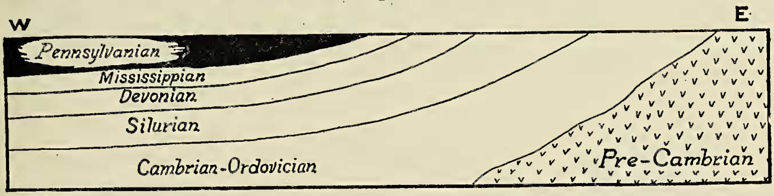

FIG. 3a. Section of Western Pennsylvania before the Appalachian Folding.

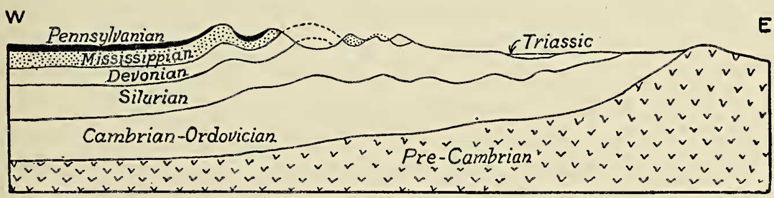

FIG. 3b. Section across Pennsylvania after the Appalachian Folding.

In Plate I is shown a geologic map of the State, in which, as is customary in most such maps, the rocks are represented as they would appear when all loose soil had been removed. The area of pre-Cambrian rocks is included in "metamorphic rocks" on the map. The reader will note the broad area or basin covered by the Pennsylvanian or "coal measure" strata, and will also see how around the margin of this area like the edges of a pile of saucers are shown the "Lower Carboniferous," or Mississippian formations, and beyond them the Devonian. The variation in this regularity due to the sharper folding and deeper erosion seen in the Laurel and Chestnut Ridges in Fayette and Somerset counties is also apparent in the two long narrow strips of "Lower Carboniferous," which represent outcrops along the eroded top of the Laurel and Chestnut Ridges.

Since the drilling of a gas-well in Pittsburgh by Mr. George Westinghouse in 1884, many wells have been drilled in or near the city and from their records we may glean much information concerning the strata beneath us. The early wells were sunk to depths of fifteen hundred to sixteen hundred feet, going through the Pennsylvanian and Mississippian divisions of the Carboniferous, and getting the gas from the sandstones of the upper Devonian. Within recent years, however, the search for deeper oil- or gas-sands has led the larger companies to drill much deeper wells, and we now have records of the strata as shown in a deep well near McDonald (7248 feet deep), a well near Bridgeport, W. Va. (7396 feet) one near Fairmount, W. Va. (7579 feet) and within the past few years a group of wells near Latrobe in the Loyalhanna Gorge (ranging from 6822 to 7750 feet in depth). There is a possibility that one of these may yet be deepened to 8000 feet.

The McDonald well passed through 950 feet of Pennsylvanian strata, 672 feet of Mississippian, 4423 feet of Devonian, and 1203 feet of Silurian. In the Silurian the drill encountered about seventy-five feet of rock-salt, a continuation of the great salt-beds of Northern Ohio and Western New York.

The Latrobe wells reached the base of the Devonian and obtained gas from the Oriskany sandstone. No doubt a well drilled in Pittsburgh would encounter about the same series of beds as in the McDonald well, with the Devonian probably somewhat thicker. No well in our district has yet reached the lower Silurian, Ordovician, or Cambrian strata, but, if drilling can ever be carried five thousand feet farther, these might yet be penetrated and the drill might reach through the whole series to the old crystalline gneisses and schists of the pre-Cambrian age.

CHAPTER III

CARBONIFEROUS STRATA

The reader now understands how our foundation for thousands of feet beneath us came to be. We may now take up the closer study of the Carboniferous rocks, which we are apt to encounter in the city, or during a short excursion into neighboring districts. Careful measurement of exposures and of the strata encountered in oil- and gas-well drilling has given us a fairly accurate estimate as to the thickness of the various subdivisions of the Pennsylvanian in Western Pennsylvania. Tabulated, with the oldest series at the bottom, they are as follows:

	Thickness in feet.
Monongahela Formation	350–375
Conemaugh Formation	500–700
Allegheny Formation	300
Pottsville Formation	100–150

Above these, and exposed principally in Greene and Washington Counties lie one thousand feet of rocks classified as Permian and representing the youngest of the sedimentary rocks laid down in the inland sea. Below the Pottsville lie the Mississippian rocks, which outcrop on some of the steeper anticlines, and which we may note in some of our longer excursions.

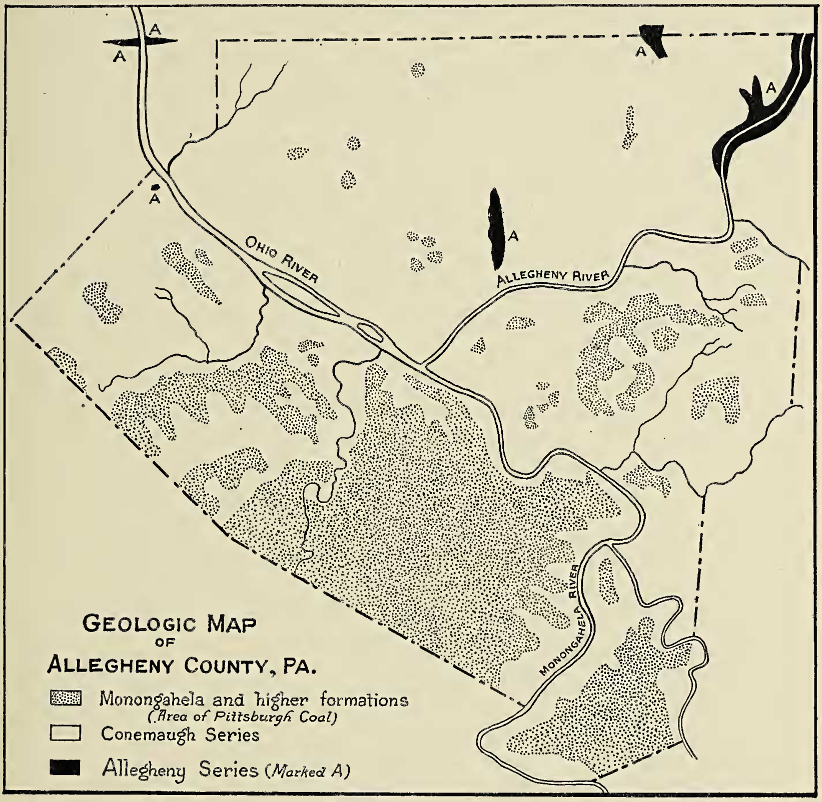

FIG. 4. Geologic Map of Allegheny County.

These four formations, however, cover the larger part of Allegheny County and their extent may be understood from Fig. 4, which represents the surface of the county and surrounding region as it would appear, if we could remove all the loose soil and decomposed rock, exposing only the hard rock. If the surface were a level plain and the rocks lay perfectly horizontally, but one formation would appear on the map. However, as we have learned, the rocks are slightly inclined, rising from Pittsburgh toward the north and toward the east, so that as we travel in either of those directions we reach the outcrop of older formations.

Conditions are further complicated by the irregularities in the surface, hilltops and highlands naturally carrying younger rocks than the valleys or lowlands. These relationships may be explained by a sketch given in Fig. 5, a cross-section showing a rock-layer which tilts in one direction, and is also dissected by numerous valleys.

Passing westward into Ohio, we also find that we reach the edge of the basin and cross the rim-rocks until at Cincinnati we are in rocks as low as the Silurian. Northward, we reach the Silurian outcrop in the gorge at Niagara Falls, while under our feet in Pittsburgh it lies possibly seven thousand feet below. Eastward, we reach the older series more rapidly on account of the more intense folding.

The Pottsville formation. The Pottsville formation seems to have been deposited under rapid stream action, a large part of it consisting

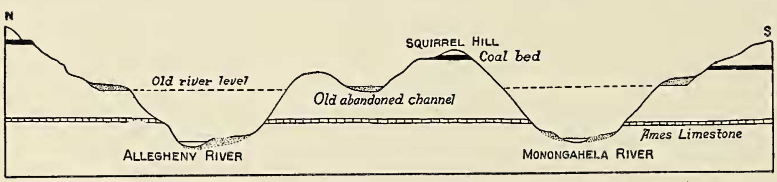

FIG. 5. A cross-section of Pittsburgh looking east, showing old and new river-valleys.

of conglomerate or coarse sandstone. It frequently lies in two thick benches: the upper known as the Homewood sandstone; the lower as the Connoquennessing sandstone. The two are separated by a zone, which carries black shale, sometimes a thin coal-bed, and often a valuable flinty fire-clay known as the "Mt. Savage fire-clay."

The Pottsville crops out prominently between Beaver and New Castle on the Connoquennessing, between Latrobe and Ligonier, above Connellsville on the Youghiogheny River, and in other outlying districts. In all of these its huge blocks of white pebbly sandstone make striking and picturesque scenery, and to the Pottsville we may give credit for some of the finest scenery in Western Pennsylvania.

Its name "Pottsville" is derived from its enormous development in the anthracite districts. Here, as also in West Virginia and Kentucky, it reaches a much greater thickness, in Kentucky attaining a thickness of five thousand feet. It often carries excellent fossils of plants, even in the coarse sandstone, and these will be referred to in a later chapter.

The Allegheny formation. During the greater part of Allegheny time, the inland sea, or Appalachian Gulf, as it is sometimes called, must have existed as a low plain almost at sea-level and covered by enormous swampy tracts; for it is during this period that the greater part of our coal-beds were being formed, the coal-beds sometimes occupying as much as one-fourteenth of the entire series of strata. The irregular lenticular character of the sandstones and shales makes us believe that the inundations of these swampy tracts and the consequent burial of the peat under these sediments was brought about by streams traversing the plain and not by deposition in the open sea. This is further emphasized by the lack of marine fossils in the greater part of these rocks, the only fossil remains being fragments of plants and trees. That there were times, during which a slight sinking of the plain allowed the sea to cover the plain, or at least to ascend some of the lower reaches, is proven by the presence of an occasional layer of limestone or shale, which carries a collection of fossils, which we know to be marine forms, such as corals, various sea-shells, etc. The whole formation is thus a series of inter-bedded sandstones, shale, coal-beds, and limestones, with coal-beds as the prominent feature. In fact, its old name was the Lower Productive Measures on account of this abundance of coal.

One of the most accessible places, where we can get good exposures of the whole Allegheny formation is in the district of Beaver Falls. Here the Pottsville sandstone outcrops in the river-bed and, rising in the cliffs and hills of the river-bank, the Allegheny series is well exhibited with the following sections:

	Feet	Inches
Coal (Upper Freeport)	3–4	
Clay	2	6
Limestone (Upper Freeport)	3	
Shale, sandy	35	
Sandstone (Butler)	30	
Coal (Lower Freeport)	1	4
Clay and hidden	3	
Shale and Sandstone (Freeport)	75	
Coal (Darlington)	1	
Shale with iron ore	35	
Coal (Lower Kittanning)	2	
Clay	12	

	Feet	Inches
Sandstone and shale	70	
Limestone (Vanport)	1	
Shale, fossiliferous	5	
Sandstone and shale	20	
Coal (Clarion)	1	
Shale	40	
Hidden to river	30	

This section gives a general idea of the formation; but from one locality to another we find a great variation. It does not, however, contain all the members of the series which are known. Among the coals, for instance, there is generally an upper and lower Freeport; an upper, a middle, and a Lower Kittanning; and toward the base of the series, the Clarion and the Brookville, the latter the lowest. In few sections, however, do we find all of these beds present. The Vanport limestone among the limestones is of the most interest, for it carries a wealth of marine forms. It covers a large area in western Pennsylvania and ranges from one to fifteen or even twenty feet in thickness. It is also known as the Ferriferous limestone, on account of the presence of nodular iron-ore above it, this name being especially used toward the east, as at Johnstown.

Tracing the limestone-areas for some distance, we often find that they grade into shale upon the borders, such a gradation indicating that the ocean covered only certain portions of the plain in the form of long narrow shallow estuaries, and that the limestone with its faunas developed in these. To see outcrops of this interesting rock it is necessary to go as far as Vanport on the Ohio, or as far as Kittanning on the Allegheny.

The upper portion of the formation, terminated by the Upper Freeport coal, lies somewhat nearer; and in passing down the Ohio can first be seen near Woodlawn and Legionville, where the Freeport coal dips to the south and passes below river-level. The first appearance up the Allegheny River is at Valley Camp and Creighton, where the Freeport coal is extensively mined. Beyond these points we enter a region, where the Kittanning coals and their associated fire-clays are utilized extensively. Under the lower portions of Pittsburgh, the upper part of the Allegheny formation, that is the Freeport coal, must lie at a depth of about three hundred and fifty feet.

The Conemaugh Formation. This formation, which crops out throughout the whole city and covers a large area in the outlying districts, especially toward the north, is the most important of all in a study of the geology of the city. From the standpoint of economic value it is of little use, being formerly called the Lower Barren Measures on account of its lack of important coal-beds.

It is underlain by the Freeport coal of the Allegheny formation, and extends upwards about six hundred feet to the floor of the Pittsburgh

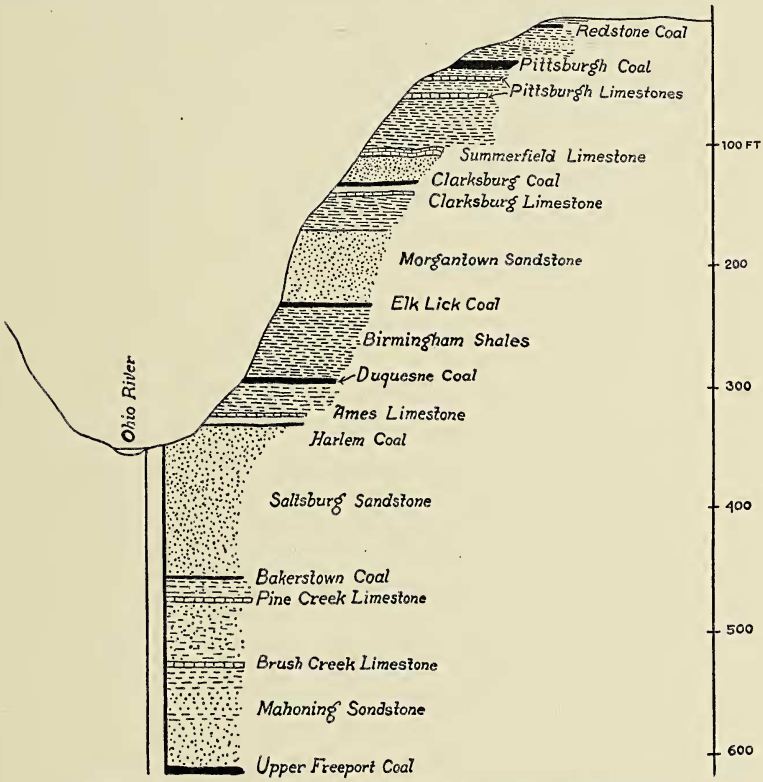

FIG. 6. Section of Conemaugh Series of Rocks at Pittsburgh.

coal-bed, the coal which is so extensively worked throughout the Pittsburgh district.

A generalized section of the Pittsburgh district would appear about as in Fig. 6, drawn to represent a cross-section of one of the hills of Pittsburgh down to river-level, and then, below that, a section of what might be expected in a shaft sunk to the Freeport coal.

From the section it will be seen that the Ames limestone divides the series into an upper and a lower half; that in the lower half are several other fossiliferous beds; and that coal-beds are thin and inconspicuous. The lower half must be studied by excursions northward into the northern suburbs, the Northside and beyond, down through Avalon and Ben Avon, or through McKees Rocks and Stoop's Ferry, or up the Allegheny on either side. The Fort Wayne division of the Pennsylvania Railroad affords excellent cliff exposures of this lower series as far down as Haysville, after which point the railroad runs mainly across a terrace, although the main macadam road affords numerous exposures through Leetsdale and Ambridge. Excellent exposures are also available in the deep side valleys such as Spruce Run, Lowrie's Run, and Killbuck Run, at the head-waters of which lies the Ames limestone. Along the southern or western side of the Ohio, fine cliff exposures are to be seen from the railroad or the roadway, especially from Coraopolis to Shousetown and up Flaugherty and Montour Runs.

Along the Allegheny Valley the West Penn Trolley line passes excellent cliffs from Montrose to Harmarville and again from Springdale through Bouquet to Creighton, while Power's, Hite's, and other runs cut back into Conemaugh strata. On the opposite side of the river the lower half of the Conemaugh begins to be seen along the railroad below Highland Park, past the Brilliant Cut-off, and onward, in fine exposures, through Nadine and Sandy Creek, and, after passing through Verona and Hulton, to Parnassus. Frequent exposures of the series also can be found along the Pittsburgh and Butler trolley-line, beyond (north of) the Butler county line. South of that line the greater part of the area traversed by these lines lies in the rocks above the Ames limestone.

Let us then begin our study of this lower Conemaugh in an excursion along the banks of the Ohio on either side and come in towards Pittsburgh from the region where the Allegheny series disappears. We find immediately above the Freeport coal an interval of sixty to one hundred feet occupied largely by thickly bedded sandstones, known as the Mahoning sandstones. They are generally found to be divided into an upper and lower series by a fire-clay and thin coal-bed, known as the Mahoning clay and coal. The sandstones show great irregularity in deposition and it is seldom that both the upper and lower beds are prominent and of value. If the lower Mahoning is thick the upper will usually be thin and shaly and *vice versa.* Frequently the lower beds carry rounded quartz pebbles, such a rock being a conglomerate, or a conglomeratic sandstone.

Beginning near Dam No. 4, we find the lower Mahoning beds outcropping near the road in Logstown Run, where it is quarried for rough building stone. It is here twenty-five feet in thickness, and shows the overlying clay with the unusual thickness of thirty-five feet. In the clay near the middle lies an important ore-bed, two feet in thickness, but no Mahoning coal is apparent. Extensive quarries in the Lower Mahoning are also found at the Park Quarries back of Freedom. Here the layers are particularly thick and solid, some of them five to eight feet thick. Here also is seen the overlying fire-clay with a thickness of eight to ten feet, a reddish flint-clay rather high in iron, while above lie thin-bedded sandstones and shales representing the upper Mahoning.

Coming east to Shousetown we find the lower Mahoning well exposed in Flaugherty Run, and going up the valley as far as the bridge, Mahoning sandstones are exposed. Opposite the bridge the top of the Mahoning group is reached and a good exposure of the Brush Creek coal is seen.

Continuing east along the railroad from Shousetown, with the greater part of the lower Mahoning sandstone below us, we may see excellent outcrops of the Mahoning clay and coal, especially at a point midway between Shousetown and Stoop's Ferry. Here are seen a four-inch and a six-inch coal-bed, separated by twenty-five feet of shaly rock, and overlain by forty feet of sandstone belonging to the upper Mahoning. Passing still farther east to an old shale-quarry we find the upper Mahoning sandstone exposed and resting upon it the Brush Creek coal and Brush Creek or Lower Cambridge limestone.

The Mahoning clays and upper Mahoning sandstone are also prominently displayed east of Sewickley along the railroad and macadam road. At the mouth of Toms Run ten feet of fire-clay are exposed, overlain by sixty-five feet of massive sandstones. The same sandstone forms the banks of Lowrie's Run through Ben Avon and the prominent railroad cuts and bluffs at Groveton, Dixmont, Emsworth, and Avalon. Overlying the Mahoning sandstone and often separated from it by a little shale lies the Brush Creek coal, a thin and generally valueless coal, averaging about one foot in thickness. This coal occupies the same position with reference to the upper

Freeport coal as does the Gallitzin coal farther east and some prefer to term it the Gallitzin coal. It is well exposed on the Shousetown-Stoop's Ferry pike, where the road bends and crosses Flaugherty Run.

Just above the coal-bed, or separated by a few feet of shale, lies the Brush Creek, better named, the Lower Cambridge limestone. This bed, though a limestone, is unusually black and is frequently shaly. It is highly fossiliferous, especially in the shaly portions and furnishes fine collecting ground for marine fossils, the first opportunity since we left the Vanport limestone. This stratum is very persistent, and can be traced or identified from the Allegheny front to northeastern Kentucky and into Maryland and West Virginia. Careful study of the fossils collected from this bed at different points shows us that important changes have taken place in the character of the fauna since the Vanport was laid down, and we find certain shells which are not present in the Vanport and miss certain others common in the Vanport. If we dare to introduce a few hard names, we may say that the great abundance of four types of coiled shells, known as *Bellerophon*, *Astartella vera*, *Euomphalus cattilloides*, and *Worthenia tabulata*, is characteristic of the Lower Cambridge.

As already noted, the Lower Cambridge generally outcrops wherever the Brush Creek coal outcrops, resting upon it, and, though rather inconspicuous on account of its dark color, any one who discovers it will be well rewarded by the fossils it contains. The old shale quarry below Stoop's Ferry affords one good exposure. Even better collecting in the Brush Creek limestone may be had at Wittmer Station near Etna, in the quarry of an old brick yard.

Buffalo sandstone and shale. Above the Brush Creek limestone for a distance of about seventy-five feet extends a variable series of shales often with a sandstone layer and generally some red shale. This series extends up to the next coal-bed, the Bakerstown coal. Since in some parts of Western Pennsylvania this interval carries a fairly well pronounced sandstone it has been termed the Buffalo sandstone. Owing to its variability it is of no great interest.

The Pine Creek, or Upper Cambridge limestone. Within the Buffalo series, however, and generally not far below the Bakerstown coal we find another interesting limestone imbedded in red shales, the Pine Creek Limestone, probably the equivalent of the Cambridge limestone in Ohio. In the vicinity of Pittsburgh this limestone has been studied by Raymond who finds it to lie sixty to ninety feet above the Brush Creek beds, and one hundred and twenty-five feet below the Ames limestone. It has been noted in many places near Pittsburgh, such as Wittmer, along the railroad three-quarters of a mile north of Wood's Run, Allegheny, and in Power's Run, Montrose. This last locality affords excellent collecting ground. Power's Run crosses the trolley line above Montrose and large blocks of the Pine Creek limestone lie in a quarry just above the bridge. From this locality Raymond has collected twenty-one species of marine fossils, of which ten are common. He found that the fauna more nearly resembles the Brush Creek than the Ames limestone, but is somewhat different from either.

The Bakerstown Coal. Above the Buffalo shales lies an irregular non-persistent coal-bed, the Bakerstown. This bed is usually very thin and non-important, but at times it attains a thickness of three feet, as at Bakerstown, in northern Allegheny County. It is generally underlain by a small amount of white clay which in turn is underlain by red clays and shales. This coal is mined at Bakerstown and is well exposed in many places in Cranberry township, Butler County. Also in the quarry of the brick-yard in Legionville Hollow at the end of the switch, where it is eighteen inches thick, while below in the run can be found the Brush Creek Limestone. Accompanying the coal, or a few feet above it, we frequently find a thin nodular limestone, which is black, or gray, and scantily fossiliferous. When dark-colored it resembles the Brush Creek limestone. The limestone and coal together may easily be mistaken for the Brush Creek Coal and limestone. This limestone, owing to its irregularity, has received no name, but may possibly represent the Portersville fossiliferous horizon of Ohio, which overlies the Anderson coal.

Saltsburg Sandstone. Some confusion has arisen regarding the Saltsburg sandstone. In some localities the name applies to sandstones beneath the Bakerstown coal, as well as to those above. The sandstones below the Bakerstown we have, however, termed the Buffalo, so that we will use the term Saltsburg as referring only to a sandstone above the Bakerstown coal. The term is thus used in the Sewickley folio. In the Sewickley district the Saltsburg sandstone varies from thirty to sixty feet in thickness, and is almost invariably thin-bedded or even shaly in character. It is exposed at many points along the Ohio valley and up the runs on either side.

Lying on the average only seventy-five feet below the Ames Limestone, we find it outcropping along the Allegheny valley on the north side, and up the river toward Nadine, Verona, etc. Especially along the Allegheny Valley Railroad, we can find good exposures, showing the thin bedding and irregularities. It is also well exposed in the cliffs on the west side of the river from the Hulton bridge towards Montrose.

Pittsburgh Red Beds. Above the shaly Saltsburg sandstones lie the Pittsburgh Red Beds, so called because of their prominent outcrop in the lower levels in Pittsburgh. From there on up through the Conemaugh formation we are able to carry on our studies in our own city streets. The topography of the city is peculiarly favorable to the geologist, for the three rivers and their tributaries have cut deep channels in the rocky layers, and from river-level to the high points, such as Herron Hill, we may see outcroppings of strata from three to four hundred feet thick. The city authorities have aided us by building numerous steps up the steeper cliffs, so that we can study the layers of rock in comfort.

We will then begin at river-level and examine the layers as we ascend. The Red Beds consist of about twenty feet of soft red clays, the bright color of which is in striking contrast to the general neutral tones of the Conemaugh. They "encircle the hills with a broad belt of blood-red soil," very sticky and troublesome and wet. They are very persistent and generally accompany the overlying Ames limestone throughout Pennsylvania, West Virginia, and Ohio, being known in the latter state as the Round Knob Beds. To these beds and the series overlying them we may properly give more attention since they outcrop within the city limits. They outcrop along the river-banks in our city and along the principal railroads. They are well exposed along the Pennsylvania Railroad going east from the Union Station and can also be seen along the Monongahela on Second Avenue and along the Allegheny River on Butler Street. Wherever seen they consist of red and purple beds, with no pronounced shaly or bedded structure, but an irregular crumbly appearance. They represent the beginning of a series of red beds which we find throughout the upper Conemaugh. There had been a long period of time represented by eight hundred feet of strata, in which practically no red beds were deposited, and to see similar but older beds it is necessary to find the Mauch Chunk red shales, which can be seen to the east near Altoona.

Their color is due to a small percentage of disseminated iron oxide. Why the Mauch Chunk and the Conemaugh series are favored by these red beds and the intervening layers are free from them is not known. Geologists generally have held that the Mauch Chunk and certain other red beds were deposited under arid desert conditions, and have offered as partial evidence the presence of sun cracks and the absence of animal or vegetable life. The Mauch Chunk shales in these and other respects are very similar to the Pittsburgh Red Beds and it is quite probable that our red beds had a similar origin. They have a uniform red color, frequently show sun cracks, and are practically free from fossil impressions. They were probably laid down under arid conditions in shallow brackish water. A few small reptile bones were found by Dr. Raymond in our red beds near Pitcairn a few years ago, while occasionally a few nodules of fossiliferous limestone occurs in them, but generally they are barren. They are of no economic value, since they are too low in iron for ore, and too high in iron for brick-making. Indeed to the farmers north of us on the outcrop they are a distinct detriment, for, when wet, they are sticky, forming plastic red muds very hard to successfully work.

Above the red beds and usually immediately below the Ames limestone we find a few inches of coal known as the Harlem coal. In most of the localities, where the Ames limestone occurs near the city, no such coal is present, but on the Northside it can be seen immediately below the Ames in the cliff behind the hotel at the corner of Rialto and Butler Streets and from there east to Walker's Station, where the Ames is well exposed. This coal is of little importance and is interesting to us chiefly in that it indicates a rather sudden change in conditions from a fresh-water swamp to a clear salty sea, in which the overlying Ames limestone was deposited. Commercially the coal is of no value, except in the Berlin Basin of Somerset County, where it is of workable thickness.

The Ames Limestone. (Pl. III, figs. 1 and 2.) In every locality, where we can see the red beds, we find capping them a layer of harder rock about two feet in thickness, standing out prominently from the surrounding softer shales and clays. This is the Ames limestone, so named from an Ohio town, where it is prominently displayed. In the older Pennsylvania Geological Reports it is often known as the "crinoidal limestone" on account of the abundance of crinoid fragments present in it. Close examination proves it to be a most interesting rock. It is seen to be a coarse grained rock of a gray or greenish color, breaking with a rough surface, and, more interesting, teeming with fossil remains. The exposed weathered surfaces are rough with jutting fossil fragments, while inside the rock seems literally made up of them. Viewing the strata as pages in the earth's history this layer, like the Brush Creek, stands out prominently as an illustrated page among many pages, the reading of which may seem to the beginner dull and hard to understand.

The Ames limestone has been traced and identified over southwestern Pennsylvania, parts of West Virginia, northeastern Kentucky, and eastern Ohio, an almost unbroken layer of rock over the entire area.

In our own district it stretches in a horizontal plane at an elevation of about seven hundred and fifty to eight hundred and fifty feet above sea-level, or fifty to one hundred and fifty feet above the river-level, outcropping along all the rivers and underlying all the hills. Accessible outcrops can be found along Second Avenue especially at the Tenth Street bridge; along Butler Street on the north side; at Sharpsburg and Aspinwall; Brilliant Cut-off; Pitcairn; Homestead Bridge; and many other places. It has always the same general appearance and about the same thickness. Its constancy both in thickness and in general appearance and its position, almost exactly one-half way between the Freeport coal below and the Pittsburgh coal above, have given it a great value to geologists engaged in studying the oil- and coal-fields. By these men it is termed an important "key-rock" and is used as a datum plane for many of their problems of structure. In drilling for the foundations of the proposed Cathedral of Learning opposite the Carnegie Museum, the Ames Limestone was encountered at one hundred and fifteen feet which at that point would make it lie seven hundred and ninety feet above sea-level.

Since it is so easily accessible to dwellers in the city we may well devote a moment to the typical fossils which are found in it. (Pl. II.) In the collection of these it is well to select blocks of the stone which are shaly or crumbly, or upon which the frost and rain have acted, for in the firmer masses the fossils are tightly embedded and cannot be easily dislodged. One of the forms of life most easily recognized will be the segments of crinoid stems. (Pl. II, figs. 2, 2a.) These appear in end view as circular disks often with a dark center which may be star-shaped. Viewed from the side they are seen to be cylindrical and jointed and have often been falsely termed petrified roots or plant stems. Their color is generally lighter than the rock around them, since their original substance has been transformed into the mineral known as calcite or calcium carbonate. These stems represent the root-like attachment by which a marine animal, a crinoid, attached itself to the sea-bottom. The crinoid was a flower-like animal consisting of this stem, or peduncle, surmounted by a cup-shaped body or calyx, which enclosed the vital organs, and from which branched out a number of arms, or tentacles. The resemblance to a flower has caused the common name of "sea-lily" to be applied to this animal. The calyx and arms are rather fragile, and are seldom well preserved, but the fragments of the stems are preserved in abundance and frequently serve to make up almost the entire rock. The crinoids, for there are many types of them, flourished most profusely in the Paleozoic seas, and their remains are common in the Silurian, Devonian, and Carboniferous rocks. At the present time they are not common in the sea, but are found in some parts of the ocean, generally in rather deep water.

The second fossil, which the searcher will probably discover, is the *Ambocœlia*, a small, smooth shell, about the size of a little finger-nail, and almost free from markings, except a gentle furrow from the hinge line down to the lower edge. Like the crinoid stems this shell sometimes makes up almost the entire rock. This shell is found only in the Devonian and Carboniferous. (Pl. II, fig. 9.)

The third form, though not so abundant as the two preceding, is larger and of more striking appearance. This is the *Lophophyllum*, a form of coral. It resembles a cornucopia, or horn, in shape, and varies from one-half to one inch in length. The horn-shaped corals are now extinct and were confined entirely to Paleozoic Seas. Within the large end of the *Lophophyllum* can be seen radiating septa or divisions. The *Lophophyllum* frequently can be seen standing out prominently on the weathered edge of the Ames limestone. (Pl. II, fig. 1.)

There are many other fossils present in the Ames limestone, the predominating group being Brachiopods, of which the *Ambocœlia* is one, and other common ones are *Chonetes granulifer* and *Derbya crassa*, while occasionally a large shell of *Spirifer cameratus* may be found. In the Brush Creek limestone the predominating shells were the Gasteropods, (Coil-shells) and such shells as *Chonetes granulifer* and *Ambocœlia* were only just appearing. The teeth of fishes, often black and shining, occasionally may be found in the Ames limestone, but, aside from these, the remains are all of crinoids, corals, and shells.

For the sake of any, who may care to further study the fossil remains of this zone, the following list of fossils collected in the Brilliant Cut-off and identified by Dr. Raymond, is given. The letter "c" stands for common, and "r" for rare.

Lophophyllum profundum c,
Hydreinocrinus sp.,
Ceriocrinus sp.,
Crania modesta r,
Orbiculoidea convexa r,
Rhipidomella pecosi c,
Derbya crassa c,
D. robusta r,
Chonetes granulifer c,
Productus cora c,
P. semireticulatus c,
P. nebraskensis r,
P. pertenuis r,
Marginifera wabashensis c,
Spirifer cameratus c,
Spiriferina kentuckiensis r,
Ambocœlia planoconvexa c,
Pugnax utah c,
Hustedia mormoni c,
Composita subtilita c,
Astartella vera r,
Edmondia aspinwallensis r,
Pseudomonotis hawni r,
Macrodon obsoletus r,
Euomphalus catilloides c,
Loxonema plicatum r,
Pleurotomaria carbonaria r,
Patellostium montfortanum c,
Euphemus carbonarius c,
Bellerophon percarinatus c,
B. stevensanus r,
Soleniscus ventricosus c,
S. paludinæformis c,
Sphærodoma texana c,
Glaphurochiton carbonarius c,
Orthoceras rushense c,
Tainoceras occidentale c,
Temnocheilus crassus r,
T. winslowi r,
Fissodus inæqualis r,
Deltodus angularis r,
Cladodus occidentalis r,
Agassizodus variabilis r,
Petalodus ohioensis c.

Above the Ames limestone, as can be seen at most of the localities, lie about five to thirty feet of variegated red-green or black shales, or clays, to which no definite name has been given. In or upon them and at some thirty feet above the Ames we may see in some localities, as at Rialto Street and near the entrance to Mt. Washington Tunnel, a one- or two-foot layer of dense limestone, free from fossils, save a minute coiled worm-like animal, *Spirorbis*, which is believed to be a freshwater animal and the rock itself is termed a freshwater limestone. It has received no name, since it is not at all persistent, though it is correlated in position with the Skelly limestone of Ohio, which is somewhat fossiliferous.

The manner in which a limestone may "pinch out" is well shown by this limestone along the cliff road south of the portal of the Mt. Washington Tunnel. (Pl. IV, fig. 2.)

The Duquesne, or *Berlin Coal*. At the top of these shales and just below the thin black shales (the Birmingham) lies a thin non-persistent coal, which Dr. Raymond has termed the "Duquesne coal" from its outcrop in the railroad cliffs near Duquesne and below Kennywood Park. It is also well exposed as a two-foot seam of poor coal on the Lincoln Road near its junction with the main Verona Road near Sandy Creek. This coal is often erroneously identified as the Elk Lick coal, which, as we shall see, lies thirty or forty feet above. The shale overlying the coal is said to contain plant remains and occasionally the teeth of fishes, and a minute shell *Estheria*, an inhabitant of brackish water. In our vicinity this coal is unimportant, but at Murdockville in the extreme western corner of the county it attains a thickness of four feet.

The Birmingham Shale. (Pl. IV, figs. 1 and 2.) Overlying the Duquesne coal and forming prominent cliff exposures throughout lower Pittsburgh is a series of thin-bedded well jointed black shales, to which the name of Birmingham has been given on account of the fine exposure near Birmingham Station at Smithfield and Carson Streets. Here they can be seen as vertically jointed dark shales at about the level of the tunnel. They are also well exposed along all the rivers, their jointed structure and curious cavernous surface being easily noticeable. It was formerly thought that the Ames limestone was the last stratum with marine fossils to be deposited and that it represented the last encroachment of the salt water over our region. Studies during the past few years have brought out the fact that this series of black shales also at times carries marine fossils, even in its upper layers, and thus it must have been deposited in salt water. As far as we now know, however, the hundreds of feet of succeeding rock carry no marine fossils, and are believed to have been deposited under fresh water in swamps, or along river flood-plains.

Elk Lick Horizon. Above the Birmingham shales, and occupying a narrow interval between them and an overlying thick-bedded sandstone are several colored bands of blue and red clay. At times this clay carries a thin nodular limestone, which corresponds to the Elk

Lick limestone of other localities, and in places also a thin black carbonaceous layer which represents the Elk Lick coal. In our district, however, the Elk Lick clay is fairly prominent, but the coal and limestone are not. The prominence of the colored clays is accentuated by the sudden change to overlying sandstone. This change can be seen on Bigelow Boulevard just above the Union Station, where we see the top of the Birmingham, the Elk Lick clays, and the bottom of the Morgantown sandstone. The clays can also be seen over the portal of the Mt. Washington Tunnel.

The Morgantown Sandstone. (Pl. V, fig. 1.) The Elk Lick clays are abruptly succeeded by a series of hard, thick-bedded sandstones, known as the Morgantown sandstone. Being hard and in thick layers it usually stands out prominently, and in our district its bold exposures are well shown along the river bluffs and cliffs. It is a most uncertain stratum, varying much in character and in thickness from point to point. At its best it is a gray or bluish-gray sandstone, full of little glistening scales of white mica, which appear especially upon the flat surfaces between individual layers. Ground down to a very thin slice and examined with a microscope, the rock is seen to be composed of sharp angular grains of quartz cemented together with finer grains of quartz and grains of feldspar, the latter partially weathered or beginning to turn to clay. Flakes of mica and a few scattered grains of hornblende and zircon may also be seen. The unusual characters of the stone are the presence therein of so many minerals besides quartz and the sharpness of the quartz grains. Sandstones as a general rule are made up of rounded water-worn grains of quartz, held together with a little carbonate of lime, yellow or red oxide of iron, or silica. The peculiar characters of this stone lead us to infer that its materials have been derived from the disintegration of granite or gneiss, two rocks containing similar minerals, and that the grains have been deposited directly with little re-sorting or abrasive action. Granite and gneiss are two of the rocks comprising the original pre-Cambrian land area to the east and we believe that the Morgantown sandstone was derived from their decay. In structure it shows many features which suggest its deposition under shallow water conditions. Frequently the layers do not lie parallel to each other but are inclined in an intricate criss-crossed arrangement. To this peculiarity we apply the term, cross-bedding. It implies the presence of cross currents in the water during deposition. The variation in the direction and velocity of the currents tends to bring the sand into irregular ridges and patches, as can be seen by a study of recent sandbanks. The bedding frequently produces a series of lenticular or long lozenge-shaped bodies of stone.

Following horizontally along an outcropping bed of Morgantown sandstone we encounter great variations in its character. From a bed of typical sandstone forty-five feet thick it may gradually change to a bed of thin-layered shale, all variations appearing, from a pure shale through a sandy shale, shaly sandstone, to the thick, hard, heavy-bedded stone. This horizontal variation is very pronounced in the Pittsburgh district, making the Morgantown an uncertain stratum in our studies. Such variation is another proof of shallow water conditions with irregular currents and irregular deposition.

A third structural feature very frequently noticed in this stratum are the "valleys of contemporaneous erosion." This feature, though awe-inspiring in name, is one that is very clearly seen and easily explained. Frequently, we find the sandstone abruptly cut off by a mass of shale. This is seen not only in the Morgantown sandstone, but in coal-beds, limestone, and other rocks. You will notice in Pl. V, fig. 2, that the sandstone tapers downward to the left and disappears and in its stead a mass of thinly bedded shale appears. At the close of the sandstone deposition a stream cut its way across the rock, cutting out a valley. The subsequently deposited strata filled this valley with a different material, giving us this peculiar structure. All of these structures, cross-bedding, horizontal variations, and erosional valleys, indicate a shallow water condition during the formation of the Morgantown. The formation is devoid of animal remains, but occasionally a plant fragment is found in it. It derives its name from its prominence at Morgantown, W. Va. It is found over most of western Pennsylvania and parts of Ohio and West Virginia, and is of commercial importance as an oil reservoir and as a building stone. In the Pittsburgh district it is well exposed in many quarries, on Bigelow Boulevard above the Union Station; near Braddock Avenue and Forbes Street; Wilkinsburg; and other places. As a building stone it is much quarried in and around the city, and although it breaks out in irregular blocks, it makes a fairly durable rough stone. Frequently it and its overlying shales are both taken from the same quarry, the shale being used in brick manufacture. Such a quarry is that of John H. Ward & Sons, near Frankstown and

Oakwood Avenues. As an oil-sand it becomes known as the Murphy Sand, and is of value where under deeper cover.

Overlying the Morgantown sandstone there are generally about twenty feet of variegated red and green clay-shales. They are frequently jointed in a peculiar manner, producing an appearance as if folded or tilted. They also often carry irregular dove-colored limestone nodules which become a source of much trouble to the brick manufacturer. These beds can be seen in many of the city brickyards, such as Sankey's on the South Side, Ward's in the East End, or the Iron City Brick Company on Stanton Avenue. The limy nodules must be carefully screened or separated from the clay used for making brick, otherwise the finished bricks would contain lumps of quicklime. This on exposure to moisture would slack and swell, breaking the brick into a useless mass.

Above these colored beds are ten or fifteen feet of black and gray shales, among which lies an easily recognized limestone layer, the Clarksburg limestone. It rarely is over one foot in thickness and has the general appearance of the other fresh water limestones. It can be seen in the brickyards mentioned above, and on the Murray Avenue car-line. It often carries small ostracods and fish remains. Above it in some parts of western Pennsylvania there lies a thin seam of coal, the Little Clarksburg Coal, but in the city this seems to be represented by a streak of carbonaceous shale about ten inches in thickness. At Bavington, near Burgettstown, the coal attains a thickness of seven feet and is workable.

The Connellsville Sandstones. Above the Clarksburg coal and limestone horizon lies an irregular and ill defined series of thick to shaly sandstone-beds very closely resembling the Morgantown beds, but less massive. The thickness of these beds is about twenty feet, including gradational beds of shaly sandstone on top and at bottom.

This is followed by fifteen feet or so of red and green shale very pronounced in color, and this in turn by the

Summerfield or Lower Pittsburgh Limestone. This bed is a typical fresh water limestone, slightly thicker than the most of the limestone beds, being usually two and one-half feet thick, parted in the middle by a thin shale. As usual it carries remains of *Spirorbis*. It can be seen on the cliffs along the Bigelow Boulevard, on the Mt. Washington cliffs, and elsewhere.

The interval between the Summerfield limestone and the Pittsburgh coal, some sixty feet, is made up of various shales, greenish, grayish, sandy, etc., in the upper thirty feet of which are imbedded seven or eight limestone beds of the fresh-water type. These are known as the Pittsburgh limestones, or the Upper Pittsburgh Limestones. (Pl. VI, fig. 1.) They generally lie in two series: *first*, a single or double bed two feet below the Pittsburgh coal, separated from it by the under clay; and a *second*, a series of four or five beds from fourteen to thirty feet lower down below the coal-bed.

These various Pittsburgh limestones can be seen wherever exposures beneath the coal are prominent, such as in the Squirrel Hill District, along the Ardmore line just out of Wilkinsburg, and even on the campus of the University of Pittsburgh along the steps leading to the Medical School. Being without fossils, save *Spirorbis*, we consider them to be fresh-water limestones. At the floor of the Pittsburgh Coal the Conemaugh Series ends and the Monongahela begins. We have seen that almost the entire city is made up of Conemaugh rocks, but that there are still some of the higher hill-tops above the Conemaugh representing the Monongahela beds. We have also seen that the Ames limestone, outcropping down near our river-levels. marks the middle of the Conemaugh; that practically all the rocks above it are of fresh-water origin, and those below show many incursions of marine conditions; that shale, especially red shales, are very common; and that coal-seams are thin and unimportant.

We will now continue our study of the Pittsburgh Coal and the rocks which lie above it and cap our higher hills.

The Pittsburgh Underclay. As is the case with most coal-beds, the Pittsburgh coal is usually underlain by from two to twelve inches of soft bluish clay called a "fire-clay." This, as we have already said, represents the floor, or basement, upon which the vegetation began its growth. Unlike the Kittanning and other of the lower clays, the Pittsburgh clay rarely shows the rhizomes of *Stigmaria*, and it is probable that the *Sigillaria* did not flourish at that period. Unlike the lower clays, the Pittsburgh clay is of little importance as a fire-clay and it is doubtful whether it has the right to the name "fire-clay." Little has been done in the development of the Pittsburgh clay and little is known concerning it. It is probably not as refractory or as valuable a clay as the lower clays.

The purity of underclays in general has been the subject of some study, and it is often thought that the detrimental impurities, iron and alkalies, have been extracted by the action of vegetable matter and organic acids, purifying and bleaching the clay.

The Pittsburgh Coal. (Pl. VI, fig. 2.) Immediately above the underclay we find the most important bed in the Pittsburgh section, the Pittsburgh Coal. In passing up from the Ames limestone we find each succeeding layer more restricted in its area, until on reaching the Pittsburgh coal we find it outcropping on the higher (almost the highest) points in the city, such as Herron Hill, the higher points in Schenley Park, Squirrel Hill, etc. To the south, southeast, or southwest, however, the bed becomes more continuous and lies as an almost continuous bed throughout Washington and Greene Counties.

Good outcrops of this coal can be seen near Murray Avenue and Phillips Avenue; opposite the entrance of Smithfield Cemetery on Beacon Street; various points in the Hill district and South Side; and on the University campus where it outcrops part-way up the hillside. This coal is an exceedingly persistent stratum, and retains its thickness and its division into "benches" over large areas. Its character and structure are best described in the Report of the Pennsylvania Geological Survey, for 1906–1908, pp. 231–232, which follows:

"The coal bed itself is readily divisible into two parts, the upper of which is known as the roof coal or division, and the lower as the main coal or division. Between them is the overlay or main clay. In parts of the area the two divisions, which are usually separated by only a foot or less, become separated by 15 or 20 feet. Then sandstone or shale as well as clay are found between the two divisions.

"The roof division has its best development at the north and in general thins to the south. In northern Washington county it attains dimensions allowing its working independently of the lower division, while in northern West Virginia it is usually lacking or thin. At the north it will measure from 5 to 6 feet in thickness. It is everywhere characterized by its clay partings. These are often extremely irregular so that detailed measurements made a few yards apart will sometimes give entirely dissimilar sections. In places the clay beds become more regular. In some sections the division is less than one-half coal, in others the clay forms one small parting. In the main, the roof division has been considered worthless and left in the mine. It now seems possible that in the not distant future it may be removed in mining and utilized in the manufacture of producer gas. The partings in the roof division are sometimes clay, sometimes shale, and frequently bone.

"The main clay or 'over-clay' is usually an impure clay, often with coal streaks, especially near the base. It will average a little under a foot. The lower division contains four benches as is shown in the following general section of the Pittsburg coal:

	Feet	Inches
Roof division	2–8	
Main or "over-clay," about	1	
"Breast" or "main" bench, often with parting in the middle	2–10	
Parting		¼
"Bearing in"		4–6
Parting		¼
"Brick" bench, about	1	
Parting, often absent or thin		
"Bottom" bench		12–20

"The breast or main coal bench is the most valuable and important part of the bed. It varies in thickness from 2 feet in Ohio to 3 feet at Pittsburg, 6 feet at Brownsville, to as high as 10 feet in the Georges creek region of Maryland. The top of the breast coal for a few inches is harder than the rest, often cannelly and frequently bony. There is occasionally a thin parting near the middle of this bench, especially toward the northwest.

"The 'bearing-in' bench which in pick mining is mined in undercutting the breast coal is a remarkably regular feature of the bed, especially with its two bounding thin shale partings above and below. The partings are usually gray mottled from ¼ inch to 1 inch thick. To the south they become bony and less conspicuous. The coal bench is a bright, pure coal from 3 to 6 inches thick. The brick coal, named from the brick-like shape of the blocks into which it mines, runs from 0 to 1 foot thick. The parting between this and the bottom bench is often inconspicuous and sometimes lacking.

"The 'bottom' bench is 12 to 25 inches thick and usually impure. The writer hopes the present season to examine this coal in the erosion channels south of Pittsburg and expects in those channels to find that this bottom bench has greatly thickened up. This is often left on account of its impurities. It could be utilized with the roof coal if that ever should be used.

"Considering the coal as a whole, the lower or working division has a thickness near Pittsburg of about 5 feet. Going southward this increases so that over the southwestern part of the State it will probably average 7 feet, ranging from 6 to 8 feet over much of Greene and Fayette counties."

It is not necessary to tell those who read these pages of the important place which the Pittsburgh Coal has held in the development and growth of our city. Our wealth in oil and gas and coal, coupled with the topographic features of the region, have been by far the most important factors in our industrial development. The earliest settlers found coal cropping out in the hills, and along the high river-banks as a continuous narrow ribbon ready for immediate mining. This accessibility along the Monongahela gives the mining of the coal a great advantage over other districts and has brought about the great system of river transportation followed by railroad transportation at river-level.

In addition to accessibility the coal is of unusually high quality, a high grade steam-coal, in some districts a gas-coal, and in the Connellsville district a valuable coking-coal. Pittsburgh Coal through these factors, has become favorably known over a large eastern territory and is shipped as coal or coke even into rival coal-bearing territories.

The higher points within the city, between the rivers, are generally capped by fifty feet or thereabout of strata lying above the Pittsburgh Coal, and included within the Monongahela series. Such outcrops can be seen at many points in the Hill District. The only rocks to be seen, however, are sandstones and shales, usually thin-bedded and of no particular interest. The hill-tops within the city limits are not quite high enough to carry exposures of the coal which next succeeds the Pittsburgh, known as the Redstone Coal. For this coal and the succeeding strata of the series we must again go to the outlying suburbs, this time going south or southwest (preferably southwest) across the South Hills into Greentree, Union, West Liberty, and Scott Townships. The Charleroi and the Washington trolley lines and the shorter lines to Castle Shannon and West Liberty afford good exposures of the Monongahela series and on some of the higher hills even the higher series are to be seen.

Above the Pittsburgh Coal in this section we generally find a portion of the roof division separated from the main coal by a few feet of shale. This has been termed the "rooster" vein, or Pittsburgh Rider. Occasionally, as at Florence, a small village north of Burgettstown, the rider is separated from the main seam by a greater thickness of strata, in this case twenty-four feet, the rider attaining a thickness of seven feet. As we have seen in the exposures in the city the remaining fifty feet of strata between the Pittsburgh coal and the Redstone coal are generally thin bedded sandstones and shales, though occasionally the sandstone becomes thick-bedded and coarse, or sugary in texture, and is known as the Pittsburgh sandstone. In some localities this interval also contains beds of fresh-water, dense, flint-like limestones, which at times, as at Bulger, make up one-half of the entire section. The Redstone coal is not a persistent thin bed, often but a carbonaceous streak, and is of no value. Like all such coals it occasionally thickens and becomes workable, but no such instances are known in this district.

The interval between the Redstone and the next, or Sewickley coal, is also one of fifty or sixty feet, and consists of shale with some sandstone layers and a few irregular limestone beds, among which is the Fishpot limestone, sometimes twenty feet in thickness in the Brownsville district.

The Sewickley Coal. This coal is usually but a thin seam or carbonaceous streak about one hundred and forty feet above the Pittsburgh coal. It is generally considered to be the equivalent of the Meig's Creek Coal of Ohio. In southeastern Greene County it reaches a thickness of five feet, but it is generally split by numerous partings and is too impure to be of much value.

The Benwood Limestone. Passing upward above the Sewickley Coal, we begin to see exposure after exposure of thick limestone beds, there being more limestone within one hundred feet of strata than seen anywhere in our study. The interval of one hundred and fifty feet or so between the Sewickley coal and the next coal-bed is frequently nearly all made up of limestone beds separated by thin beds of shale. In the older reports the entire section was considered as a unit and termed the "Great Limestone," but more careful study has brought about a subdivision of the limestone into two divisions; the upper being the Uniontown, and the lower the Benwood, separated by fifteen to twenty feet of shale. In the Benwood limestone itself geologists find beds of such strong characteristics that it has seemed well to give them names. Southwest of Pittsburgh we find a lower creamy white bed, four feet thick, called the Dinsmore; and an upper brown bed, one to two feet thick, called the Bulger. These, with less characteristic beds, make up the Benwood limestone. All are dense fresh-water limestone, carrying no fossil remains save small ostracods.

The Uniontown Limestone. This is separated from the Benwood limestone by limy shale and attains an average thickness of ten feet in several benches, each one foot in thickness. These various layers on exposure weather in our district in a peculiar way, the lowest becoming covered with small projecting spots like pimples; the second showing light and dark spots; the third becoming covered with a white clay, and the upper layer becoming soft and yellow. When natural cement was more popular than it is today, this limestone was burned to make cement and is said to have yielded an excellent product.

The Uniontown Coal. A few feet above the Uniontown Limestone a coal blossom is frequently seen. It is not of workable thickness, its maximum thickness being but twenty inches. Above this coal there lie twenty to forty feet of uninteresting sandstones and shales, followed by another bed or series of beds of fresh-water limestone, the Waynesburg Limestone. This is in turn overlain by a thin streak of coal or black shale, the Little Waynesburg coal. Then, following an interval of twenty-five to forty feet of shales and sandstone, we reach the Waynesburg coal, the uppermost layer in the Monongahela series. This coal ranges from a few inches to ten feet in thickness, but the thicker portions are usually hampered by clay-partings. It is locally mined, wherever it yields five or six feet of coal, but, so long as the Pittsburgh bed is easily accessible, the Waynesburg coal must generally remain unworked.

The rocks deposited after and upon the Monongahela series lie mostly southwest in Washington and Greene Counties and are not properly to be considered in this discussion. These rocks, which in Greene County attain a thickness of over a thousand feet, from a careful study of the fossil plants contained therein are believed to be of Permian age, and are termed the Dunkard Group. The lower portion resting upon the Waynesburg coal is the Washington Formation, and the upper the Greene Formation. In nature they are much like the Monongahela series, consisting of shales, sandstones, limestones, and occasional unimportant coal-beds. Among the interesting fossil beds in the Dunkard Group is the Cassville shale overlying the Waynesburg coal. This is famous as a source of well preserved fossil plants and insects, especially cockroaches. A second fossiliferous layer is found in the lower Greene formation, two hundred and seventy-five feet above the Cassville Shale. This layer is called the Fish Bed or Beds, since it carries many fish scales, as well as bivalves and impressions of leaves.

With the deposition of these higher strata in the southwestern corner of the state, the land surface rose, and the carboniferous sea or land-locked estuary, or river valley was obliterated. The long period of construction was at an end. Destruction was soon to begin. Forces were at work to the eastward crumpling the rocks of the central region into great waves, or folds, while the thousands of feet of sediment in western Pennsylvania were elevated with but slight warping. Throughout the succeeding ages, the Cretaceous and Tertiary, we shall see that the history is simply one of a struggle between the forces striving to tear down and plane off the topographic irregularities and the forces of re-elevation, and that the surface topography tells us of the alternate successes of these two forces.

CHAPTER IV.

AFTER THE CARBONIFEROUS.

When the final layers of sandstone, shale, and coal had been deposited in the Greene and Washington county lowlands and the great Carboniferous Period came to a close, the great thickness of sediments, which had been accumulating in the inland sea or Appalachian trough, gave rise to movements of the crust of the earth. The weight of sediments had no doubt overloaded the crust and a crowding, thrusting movement took place, which slowly buckled the layers in central Pennsylvania into a series of upfolded and downfolded (anticlinal and synclinal) ridges, the structure of which is today well displayed in the central counties. In western Pennsylvania the movement uplifted a large area as a plateau the foundation rocks of which were but slightly folded.

During the succeeding Mesozoic and the early Cenozoic era, our section was a land area subject to the usual forces of destruction, erosion, and weathering, which were tending to reduce the elevated land to the level surface of a peneplain, while occasional renewed uplifts tended to counteract denudation, as has been shown in the chapter on Physiography.

The Cretaceous and Tertiary seas were in existence elsewhere, and our knowledge of the life and conditions prevailing during these periods must depend on the study of deposits and their fossils made in our western states, or elsewhere.

The close of the Tertiary period finds the rivers of western Pennsylvania flowing in broad flat valleys, so near to their base-level, or sea-level that they were widening rather than deepening their valleys. This is the period of the Parker Strath, mentioned in Chapter I. These rivers were not entirely in the same channels, which they now occupy.

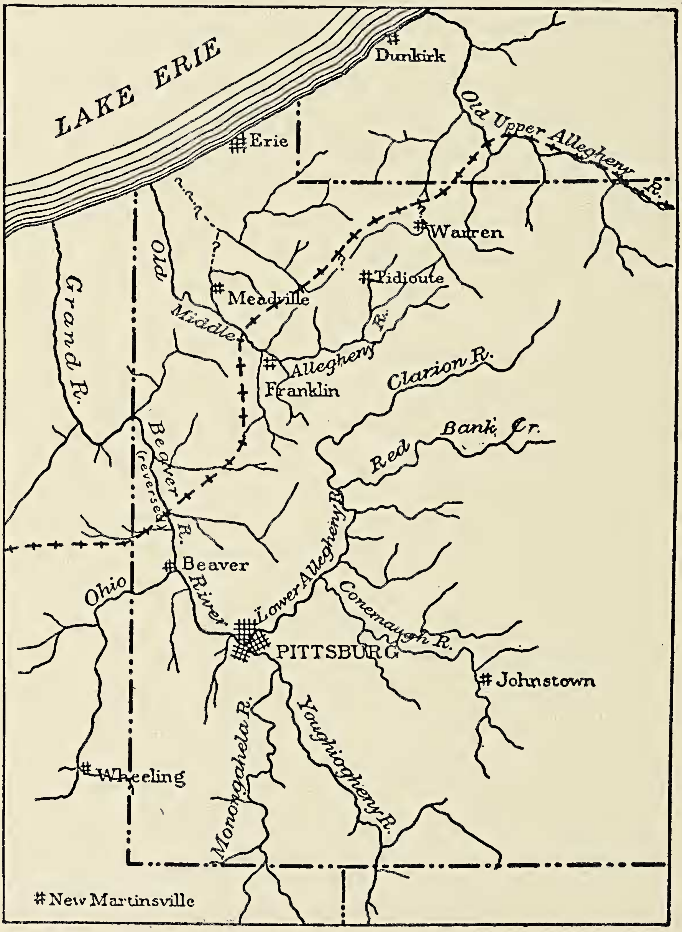

FIG. 7. Sketch map, showing the probable pre-glacial drainage of western Pennsylvania. The terminal moraine is shown by a broken crossed line. (After Frank Leverett, with addition of terminal moraine.)

It may here be noted that it is very probable that the divide between the water-sheds of the St. Lawrence drainage and the Gulf of Mexico in the region of the Allegheny valley stood at Emlenton, and that the Allegheny, known to geologists as the "Old Lower Allegheny," was made up mainly by the union of the Clarion and Red Bank Rivers. The system of rivers north of the old divide then flowed into a stream which had its bed somewhere in what now is Lake Erie. From Pittsburgh the Ohio, carrying the waters of the Monongahela, flowed north past Beaver and continued north along the course of the present Beaver River and through the Grand River into the St. Lawrence drainage. That portion of the Ohio from Wheeling to Beaver also flowed north as a tributary of this system. All the streams of western Pennsylvania and West Virginia discharged their waters at that time through the Gulf of St. Lawrence into the Atlantic and did not flow to the Gulf of Mexico (See fig. 7).

At the close of the Tertiary the whole of the northern United States came under the grip of a rigorously cold climate. Ice and snow were formed in such amounts that the warm summer sun could not melt them, and an immense continental ice-sheet crept down from centers of accumulation in Labrador, the region of Hudson's Bay, and Western Canada. This sheet, often several thousand feet in thickness, overrode the highlands, scoured off the surfaces, scratched and scored the underlying rocks like an immense plane. The earliest advance of the ice, the Kansas stage, reached down into Western Pennsylvania till its front extended from a point a few miles north of Beaver, northeast to and beyond a point north of Warren (Fig. 7). To this line the advancing glacier brought enormous quantities of sand, gravel, and clay, torn from any or all rock exposures to the north or northwest. Although the ice-front did not reach as far south as Pittsburgh, its effects upon the district were nevertheless of great importance.

The principal effect was upon the drainage systems. The thick mass of ice and its attendant tons of debris impounded the streams flowing northward, as above described, and finally caused them to break over barriers and flow southward, thereby uniting the streams of the upper Allegheny district with the lower stream, giving us a great waterway which rises but a short distance from Lake Erie, yet flows into the Gulf of Mexico. The Beaver River was reversed. Its waters with those of the Ohio were backed up from a point near

Wheeling, and finally found in that direction a surmountable divide perhaps near Moundsville. This accounts for the peculiar course of the Ohio and its sharp bend at Beaver. These changes in the drainage had a profound influence upon the history and economic development of Pittsburgh.

The new Allegheny soon became overloaded with glacial material and gravel torn away during the cutting of the new divides. This load was strewn along the bottom of the valley forming a wide strath to the depth of about one hundred feet of sand and gravel, over which the river wound its way at this much higher level. The tributaries also, although not carrying an excessive amount of debris, were obliged to accommodate their gradient to that of the main stream and with a lessened velocity they also built up a thick bed of sediment near their mouths, the sediment thinning out up stream. The rising of the rivers made it possible in many cases for them to flow in new channels, and at different stages they probably had several channel-ways, with islands of higher land between. These channel-ways also gradually became somewhat filled with sediment, or "silted up."

Following this stage came an interglacial epoch. A warmer climate prevailed and less and less ice formed, until the whole Kansan ice-sheet had practically disappeared from our state. This interglacial epoch lasted a long time, during which the surface of the land slowly rose three hundred and fifty feet, thus increasing the velocity and cutting power of the streams. They cut a narrow channel through the loose sediments and finally ate their way down to, and even through, the hard rock-floor of their old channels. In making this new course, they abandoned some of the winding loops and side-channels occupied during their flow at higher levels, generally, but not always, choosing the shorter channel.

Now! What were the results of this renewed cutting? The remnants of the old wider channel were left on either side of the new and narrower gorge as terraces, with flat rock-bottoms and a covering of gravel. The abandoned channels also were left high and dry above the new stream-levels. This is exactly what we find along all of our streams. At an elevation of approximately two hundred feet above the present river-level, we find the rock-shelves, and upon them we sometimes find the original sand, clay, and gravel lying as deposits one hundred feet higher (Fig. 5). Often, however, erosion, or human activities have removed the loose cover from the terraces. These terraces extend along the Allegheny and the Ohio, where they are covered with glacial gravels; and also along the other rivers and streams, where they are covered by local gravels and silts, materials which have not the heterogeneous character of the glacial drift. The tops of Monument Hill, Troy Hill, and Boyd's Hill, Pittsburgh, the flat terrace forming Kennywood Park, parts of Sheraden and Elliot, parts of the Allegheny Cemetery, and many other places in the district carry remnants of the material laid down at the time of this old river-level. Forbes Street from the city out through Oakland runs on a rock-shelf of this character. With the help of topographic maps one may trace many of these terraces, lying between the nine hundred- and the one thousand-foot contour-lines, *i. e.*, nine hundred to one thousand feet above sea-level.

Broad abandoned valley loops and elevated terraces also are prominent along the Monongahela River. Among them are the site of Kennywood Park, the loops back of McKeesport, and a loop near Belle Vernon. On the Monongahela River terraces the materials consist of fine silts and clays with occasional deposits of gravel or boulders. The deposit is usually known as the "Carmichaels formation." In many cases it has the appearance of having been formed in sluggish water, or in a lake; and some years ago the prevailing theory was that during the glacial period a large lake occupied the Monongahela Valley, and that the Carmichaels deposits were lake-beds. The noted geologist, G. F. Wright, believed that an ice-dam for a time choked the Ohio River near Cincinnati and that a body of water was impounded in the upper Ohio, the Allegheny, and the Monongahela Rivers. Geologists have generally abandoned Dr. Wright's view. Later Dr. I. C. White came forward with the theory that while the Ohio River was still flowing north past Beaver Falls, the ice-sheet blocked its flow and impounded "Lake Monongahela" in the valleys to the South. He maintained that this lake had an outlet or outlets, in the vicinity of Salem, West Virginia, and discharged westward into the Ohio. He contended that the lake was drained and the present river-channels were established, when the water in the upper Ohio Valley succeeded in breaking over and through the divide near Moundsville, and allowed the flow from our rivers to become a part of the Mississippi drainage.

The theory of a lake and lake-deposits has latterly been questioned and arguments have been advanced in favor of the ideas outlined in this chapter; namely, that these deposits in the old rock channel are flood-plain deposits, made at a time when the volume of the rivers was augmented and much silt was available. Some ponding of the northward flowing streams when the ice-sheet crept down from the north is unquestioned, and there is no doubt that their northward flow was stopped at the time, when they began to flow southward. However, the upper surfaces of the gravel and silt deposits slope, as do the streams, and this fact leads the writer to think that they could hardly be lake deposits. Nevertheless it is proper to observe that the coincidence of the slope of the rivers and the terraces we are discussing is by some attributed to an upheaval of the whole region at the height of the glacial period. The writings of Wright, White, Chamberlain, Leverett, and others furnish very interesting discussions of this topic.

The next event of importance in the glacial history of the rivers was the advance of the Wisconsin ice. This second glaciation loaded the Allegheny with glacial drift to a depth of possibly one hundred and fifty feet, and fifty feet of this load still lies in the bottom of the rivers, while in various terraces as high as one hundred feet above river-level we find these Wisconsin gravels.

These lower gravel-terraces furnish the sites for many of the river towns, Coraopolis, lower Allegheny, Sewickley, Verona, Springdale, Sharpsburg, etc. They also are much used as sources of building gravel and can be seen in many excavations made in lower Pittsburgh.

The glacial gravel dredged from the Allegheny, or stripped from these terraces, makes an interesting study, and a half-hour spent on almost any gravel-pile, where building operations are in progress, will yield a wealth of specimens of rock. Being glacial material, we find in it pebbles from localities far to the north, even from Canada. We find red Medina Sandstone from the Medina region of New York State between Buffalo and Rochester; we find corals, many of them changed to silica and similar to those found in the solid rock in western New York; conglomerate from Olean, N. Y.; beautiful granites, darker gabbros, and banded gneisses from the rocky pre-Cambrian districts of Ontario. The writer has even seen in the gravels copper ores which can only have had their origin in northern Michigan near Houghton.

Before leaving the subject of glacial deposits, the writer feels that special attention should be called to a most interesting little book to be found in the Carnegie Library, entitled "River terraces in and around Pittsburgh," written some twenty years ago by Prof. B. C. Jillson. He describes in a most entertaining manner many of the terraces of early Pittsburgh, terraces which are now almost obliterated by the growth of the city, and those who recall the early days will find it very instructive. Ask for it some day when in the library.

From the deposition of the Wisconsin drift to the present time (a comparatively short time, speaking geologically) no great changes have taken place. The topography has been somewhat lowered by further dissection and the streams in places have formed alluvial flood-plains, but time has not been sufficient to work great alterations.

The deepening of the main rivers during the glacial period has given to all the small side streams a very steep grade and many of them therefore have flowed very swiftly and have cut their way downward very rapidly until they now flow in narrow ravines. Examples are to be seen in Fern Hollow near the Frick Woods and Squaw Run in Aspinwall and in practically all the smaller tributaries. These small streams are gradually eating their way back into the higher plateau and carving, or dissecting it into a network of hills and valleys.

The human race probably developed during, or immediately after the Glacial Period, and with the advent of man human history begins. Of this human side of the story we have in the region the scanty records left by the aborigines in their burial mounds and rock-carvings.

We must continually keep in mind, however, that the elevations of the land, the deposition of sediments, the formation of strata, the coming of the ice-sheets, and all these startling phenomena were not, as we used to believe, unusual and sudden catastrophies, but were events which consumed thousands of years. Our land-surfaces are even now either rising or falling, although we can barely measure the change from century to century; our streams and oceans are forming rock-strata as in the past. We may be living in a long inter-glacial epoch, and even now a new glacial period may be on its way, so slowly do such events progress. The past was not so very different from the present, except that we must accustom ourselves to thinking in terms of hundreds of thousands of years in place of centuries.

CHAPTER V.

FOSSIL HUNTING.

Animal Remains.

Many nature-lovers, who may have examined our cliffs for fossils and found none, may by this time realize that the mode of deposition of most of our rocks in rapid, sandy, or muddy streams, or flood-plains, was not favorable to animal life and rather destructive to plant-life. In the sandstones we may find a few fragments of trees or broken and torn leaves, little else; in the red shales we need look for no life; in the black shales we may expect to find fairly well preserved fronds of ferns and other delicate plants; in the calcareous (limy) shales we are apt to find an abundance of marine shells, easily extracted; while in the limestones we really find the best field for collecting marine life. Many of our limestones, especially just above and just below the Pittsburgh coal are dense and practically barren, having been formed, it is thought, in fresh water. For plant remains the black shale overlying a coal-bed furnishes the best source; while for marine forms in our district the three marine limestones lying in the lower Conemaugh formation must be located. The shaly portions of the limestones are usually more easily broken up than the harder parts and the fossils can be more safely and perfectly extracted. Blocks which have been exposed to the rain and frost are also much more amenable to the hammer than fresh exposures. Old quarries, old brick-yards, railroad or road embankments are ideal collecting spots. The collector should be armed with a prospector's pick or bricklayer's hammer, a haversack, paper for wrapping specimens, and a few pill boxes or "Bull Durham" tobacco bags for delicate specimens. He (or she) should wear rough shoes for climbing cliffs, and clothes suitable for sitting in the dirt, for he who tries to find much material while in a standing or stooping position will be seldom rewarded.

The highest stratum carrying marine life is a sandy layer at the top of the Birmingham shale. It contains a few sparsely scattered species. Down through the Birmingham and the intervening strata there is small chance of finding any forms until the Ames limestone is reached. As described in a preceding chapter, it is our most important collecting zone.

There is always a certain zest given to the collector in finding his own localities, but as a beginning it might be well to list a few localities where we have found good collecting, but bear in mind that there are plenty of spots in the district, which may afford even better material, which we have not as yet detected.

Among the best, most easily accessible spots is the Brilliant Cut-off of the Pennsylvania Railroad (Pl. III, fig. 2). Walk north on Washington Boulevard from Fifth and Hamilton Avenues, East End, past Silver Lake, and on until you are almost at the turn near the river; climb the steep bank to the right and between the bank and the tracks you will find an abundance of well weathered blocks of Ames limestone. This spot may also be reached by paths, which lead down the steep hill from Highland Park.

A second spot is a small outcrop near the Homestead Bridge. Take a Homestead car by way of Murray Avenue, and get off at the north or nearest end of the bridge. Walk back along the track to the first sharp bend and there you will find a small outcrop of the Ames limestone.

A third locality lies between Wilmerding and Pitcairn. Take any trolley going to Pitcairn, such as the Trafford City Express, and get off at almost any stop between the Wilmerding bridge and Pitcairn. The Ames outcrops along the track for a long distance and many blocks of it lie in the fields south of the trolley track, also in the quarry of the brick-yard at Pitcairn.

Now, what will you find in the Ames limestone? The fossil which will first strike your eye will be, no doubt, the *Lophophyllum profundum* (Pl. II, fig. 1). It resembles an ice-cream cone in shape, is between one-quarter and one inch in length, and its cross-section shows radiating septa like a cut orange. It is a coral and is the most abundant coral in the Ames limestone, in fact, the only one you will be likely to see.

You next would probably notice a small smooth white shell like a very small finger-nail, but with a groove down through the center. This is *Ambocœlia convexa* (Pl. II, fig. 9). It belongs to the family of shells called brachiopods, and is so abundant as to make granular masses, of which it is the main constituent.

A small cylindrical stem like form may possibly attract the eye. This is the stem of some crinoid (Pl. II, figs. 2, 2a). It is a marine animal, often called a "sea-lily" on account of the flower-like head with tentacles branching from it like petals. The stem which we may discover was that portion of the animal by which it was attached to the rocks. It varies from one-eighth to one-half of an inch in diameter, and portions sometimes can be found several inches in length. It easily breaks into segments and often carries a core which may be star-shaped. The crinoid stems are so prominent that in older reports the Ames is often called the "Crinoidal Limestone." The head of the crinoid (or in reality the body and the branching arms) is unfortunately made up of plates and segments easily separated, and no good specimens have been found in the Ames limestone, although an experienced collector occasionally finds small segments and plates.

You may be so fortunate as to find a fairly well preserved *Spirifer cameratus* (Pl. II, fig. 8), but more often they are broken or crushed. It, like the *Ambocœlia*, is a brachiopod, but one of the larger species, often measuring one or one and one-half inches in width. Among the typical and extremely abundant brachiopods of the Ames limestone is *Chonetes granulifer* (Pl. II, fig. 5), a thin, delicate shell, about the size of a finger-nail. It often breaks out so as to show both the inside and outside surfaces of one valve, in which case it is thin and must be handled with care.

Another brachiopod, which in some localities is quite abundant, is *Marginifera wabashensis* (Pl. II, fig. 7), a shell about the size of a thumb-nail, but with one valve very much distended, a fat-looking shell. Its surface bears a number of spines and, though it is seldom that the spines are preserved intact, their stumpy bases show upon the surface of the shell. In the Ames limestone this shell is usually very lustrous, since the original mother-of-pearl seems to be preserved, and, if one carrying good spines is found, it makes a handsome specimen.

A shell somewhat resembling the foregoing, but of larger size and usually with less prominent "wings," is the *Productus* (Pl. II, fig. 6), of which in the Ames limestone there are several species very much alike. The shell is seldom as lustrous, but is often roughened by the traces of spines, as in *Marginifera*. *Derbya crassa* (Pl. II, fig. 4), is a very flat shell often flattened in the Ames limestone to almost a plate-like form, very pronouncedly ribbed, and often black in color through impregnation with phosphatic solutions.

Two small shells, which may take some patience to discover, but which are well worth the effort, are *Pugnax utah* (Pl. II, fig. 12) and *Hustedia mormoni* (Pl. II, fig. 11). They are about the size of a little finger-nail and are strongly corrugated, *Pugnax* being less symmetrically grooved and showing less perfect corrugations than *Hustedia*. From the illustrations one will have no trouble in distinguishing them.

Composita or *Seminula subtilata*, is a shell, the hinge of which is rather pointed, while the surface shows no vertical grooving, save one slight medial wave, but the surface of which is marked by slight concentric lines paralleling the edge of the shell. The shell is about the size of a thumb-nail, or slightly larger. You are quite likely while collecting to run across one of the coil-shells or snail-shells, and the form will probably be a *Sphærodoma*, although other genera of this class, the *Gasteropods*, are known to occur. The *Sphærodoma* (Pl. II, fig. 15) is a coil-shell, which carries about four turns or whorls, and comes to a very sharp point. In the Ames limestone these shells are often so flattened as to be at first hardly recognizable as cylindrical in form. They are generally black and partially phosphatized.

Still another unusual form of life is the *Orthoceras rushense*. The *Orthoceras* is a pencil-like cylindrical shell somewhat tapering and cross-jointed in segments. It, too, is often flattened and crushed by pressure (Pl. II, fig. 16).

Occasionally, in the Ames limestone, there are found fragments of large flat coil-shells. The fragments may be two or three inches long and are usually blackened with phosphate, and may usually be recognized by the fact that they carry several projecting humps, or points, which are in one or two rows around the shell. The fragments are seldom large enough for accurate identification, but they often belong to shells of the genus *Tainoceras*, or *Metaceras*.

About the only other forms noticeable in the Ames limestone, are small black irregular lumps, or nodules, which are not fossils, but nodules of phosphate of lime, which are often found in limestone, or upon the present ocean floor.

In the year 1907 Professor P. E. Raymond, at that time Curator of Invertebrate Paleontology in the Carnegie Museum, found some bones representing reptiles and amphibians in the red clay underlying the Ames limestone at Pitcairn, east of the city. The clay at the point where the discovery was made is thirty-seven feet thick. Some of the bones were found lying upon a layer of nodular limestone about three feet above the base of the clay and the rest imbedded in the clay about a foot higher up. A preliminary report of the discovery was published by Raymond in *Science*, N. S., Vol. XXVI, 1907,

p. 835. The specimens were sent to Professor E. L. Case of the University of Michigan, whose report upon them appears in the Annals of the Carnegie Museum, Vol. IV, 1908, pp. 234–241, pl. LIX. Some of the remains represent animals of considerable size for the orders to which they belong. The fossils were referred to genera which are well represented in the Permian beds of Texas, and are interesting because they show the existence of such forms at a point in the geological scale many hundreds of feet below the point where they occur in Texas. One of the fragments obtained by Prof. Raymond was assigned by Professor Case to the genus *Naosaurus*, belonging to a curious order of carnivorous reptiles known as the *Pelycosauria*, all long ago extinct. In fig. 8 we give a picture of the skeleton of

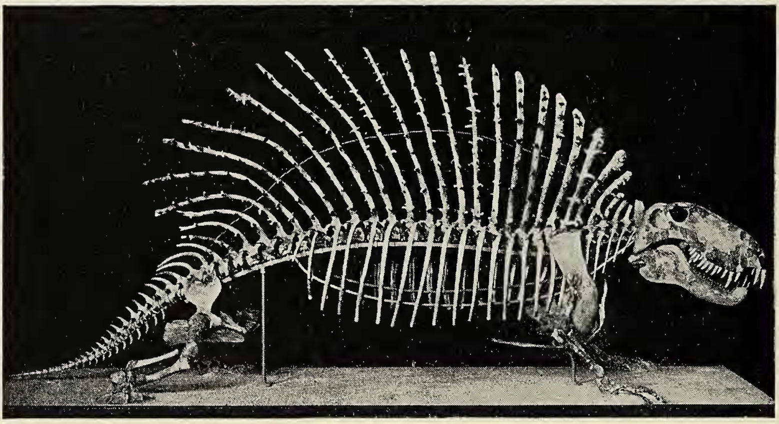

FIG. 8. Photograph of the restored skeleton of *Naosaurus* in the American Museum of Natural History. Reproduced by the courtesy of that museum. One-tenth natural size.

a *Naosaurus* which has been restored and placed on exhibition in the American Museum of Natural History in New York, to the authorities of which we tender thanks for being permitted to use it. This old Pittsburgher, whose bones were found in the suburbs at Pitcairn, was a "prickly fellow," and any creature, which tried to bite him, no doubt found that he had "a mouthful." *Naosaurus* was from three to four feet long. The amphibian remains belonged chiefly to the genus *Eryops*, much larger than any amphibians of the present day.

In an epitome of his researches upon the fauna of the Allegheny and Conemaugh series of rocks by Raymond, published by the Topographic and Geologic Survey Commission of Pennsylvania, 1909–1910, pp. 83–96, Raymond lists the species.

In the last mentioned paper, Raymond also notes the discovery of a fossiliferous limestone on Woods Run, California Avenue and Brighton Road, Northside, and lists fossils collected there.

The next fossiliferous zone of any great importance is the Pine Creek limestone which lies one hundred and twenty feet below the Ames limestone. Two good collecting places for this layer are found at Wittmer and at Powers Run. Other exposures lie in the ravines back of Emsworth and Avalon. To reach Wittmer, take a B. & O. train, which stops at Wittmer, a station between Etna and Glenshaw, or take an Etna trolley-car and either walk or take the bus to Wittmer. There you will find, west of the road, a high bluff, from which shale has been quarried in several benches for brick-making. The top of the first bench carries the Brush Creek limestone. Sixty feet higher, on the second bench lies the Pine Creek limestone, and numerous blocks of it lie scattered around. In that locality it can be recognized by the fact that its upper and lower surfaces seem more resistant to weathering agencies than the middle and its exposed edge is therefore concave. This characteristic holds good for most of the outcrops seen in northern Allegheny County. The Powers Run locality is reached by taking the Allegheny Valley trolley to Powers Run, a stop above Montrose. To the west, up Powers Run, there runs a cliff, from which some sandstone is quarried. The Pine Creek limestone can be seen outcropping half-way up the cliff, and there are many shaly decomposed lumps scattered at the base which furnish excellent material. The life in the Pine Creek limestone varies but little from that of the Ames limestone. *Chonetes granulifer* seems to be lacking, and some other forms are more prominent. Forms rarely seen in the Ames limestone, but especially abundant at Wittmer in the Pine Creek formation, are the Bryozoa (Pl. II, fig. 3). These are found on the upper surface of many of the blocks, as branching moss-like growths, like sea-weeds, made up of colonies of very small animals. They lie on the rock surface as a mat of branching material. Another type of fossils which the writer has found in well preserved specimens are certain of the lamellibranch shells, resembling our fresh water clam, or mussel, the commonest being *Allorisma subcuneatum* (Pl. II, fig. 13). Enormous *Producti* as large as walnuts, are very common but hard to extract. *Composita subtilata* is common, *Lophophyllum* very abundant, in fact, most species of the Ames list are repeated in the Pine Creek.

Sixty feet below the Pine Creek lies the Brush Creek limestone and there is no better locality for it than the Wittmer cliff. The lower bench has for its floor about a foot of hard black limestone, while (for some feet above and below this) the shales are black and fossiliferous. Many other localities of Brush Creek should be found in the beautiful ravines north of the Allegheny River. The striking feature of the Brush Creek, aside from its abnormally black color, is the presence of so many and such perfect Gasteropods (snail-like shells) especially *Worthenia tabulata* (Pl. II, fig. 14), which differs from *Sphærodoma* by the angular nature of its whorls. Most of the fossils described from the Ames limestone may be found also in this stratum, the principal exception being *Pugnax utah*, which does not appear in the Brush Creek bed.

The following is a tabulated list of the species found in the Pittsburgh district with the strata in which they were found and a reference to their illustration. This was arranged from Raymond's paper (*loc. cit.*) by Prof. R. H. Johnson of the University of Pittsburgh. It is inserted for the benefit of those who may wish to identify the fossils they may find:

FOSSILS OF THE CONEMAUGH FORMATION NEAR PITTSBURGH.

Class	Species	Illustration	Horizon
Coral	Lophophyllum profundum	Girty 2, 1	BPWA
Crinoids	Ceriocrinus craigi	Raymond 4, 2	BP
	Hydreionocrinus sp.	Girty 3, 3	A
	Columns & plates of crinoids	Girty 3, 1	BPWABi
Bryozoa	Septopora (Synocladia) biserialis	Raymond 4, 1	P
	Rhombopora nicklesi	Ulrich	BP
Brachiopods	Lingula umbonata	Grabau 229k	Br.
	Orbiculoidea missouriensis	Grabau 236e	P
	" convexa	Grabau 236d	A
	" planodisca	Raymond-Annals 28, 12	Bi.
	Crania modesta	Girty 6, 12	A
	Rhipidomella pecosi	Grabau 321a	A
	Derbya crassa	Girty 7, 1	BPWA
	Chonetes verneuilanus	Schuchert 23, 4	BP
	" granulifer	Girty 7, 12	BP
	Productus semireticulatus	Schuchert 23, 10	BPA
	" cora	Girty 8, 4	BPABi
	" nebraskensis	Girty 10, 6	BPWBi
	" punctatus	Schuchert 23, 9	BR
	" pertenuis	Girty 8, 3	BA
	Marginifera wabashensis	Norwood & Pratten 1, 6	BPA
	Spirifer comeratus	Girty 11, 4	BPA
	Spiriferina kentuckiensis	Girty 11, 8	PWA
	Ambocoelia planoconvexa	Girty 11, 6	BPA
	Composita (Seminula) subtilita	Girty 12, 4	BPA
	Cleiothyridina orbicularis	Girty 12, 1	PA
	Hustedia mormoni	Girty 12, 5	A
	Pugnax osagensis (utah)	Grabau 656	BA

Class	Species	Illustration	Horizon
Pelecypods	Deltopecten occidentalis	Grabau 656	BA
Pelecypods	Acanthopecten carboniferous	Girty 27, 10	BPBi
Pelecypods	Psendomonotis hawni	Schuchert 23, 17	A
Pelecypods	Yoldia carbonaria	Meek	Br
Pelecypods	Leda (Nuculana) bellistriata	Girty 14, 1	BP
Pelecypods	Nuculopsis (Nucula) ventricosa	Girty 15, 1	BPA
Pelecypods	Edmondia aspenwallensis	Grabau 494	PABi
Pelecypods	Allorisma subcuneatum	Raymond 6, 5	BPABi
Pelecypods	" costatum	Grabau 706	Bi
Pelecypods	Schizodus cuneatus	Grabau 644	Bi
Pelecypods	Macrodon (Parallodon)		
Pelecypods	" " tenuistriatus	Condit 15, 2	P
Pelecypods	" " obsoletus	Grabau 518	A
Pelecypods	Astartella vara	Raymond 5, 8	BA
Pelecypods	Cardiomorpha missouriensis	Grabau 490	Bi
Gastropods	Platyceras parvum	Grabau 970	BPA
Gastropods	" spinigerum	Worthen 28, 4	Br
Gastropods	Schizostona (Euomphalus)		
Gastropods	" catilloides	Girty 21, 4	BPA
Gastropods	Bulimorpha (Meekospira) nitidula	Grabau 1003c	BP
Gastropods	Trepospira illinosensis (depressa)	Girty 21, 6	BP
Gastropods	Worthenia tabulata	Girty 22, 1	B
Gastropods	Phanerotrena grayvillensis	Girty 23, 2	B
Gastropods	Pleurotomaria carbonaria	Raymond 5, 1	BA
Gastropods	" perhumerosa	Meek 4–13	B
Gastropods	Euphemus carbonarius	Girty 21, 1	BA
Gastropods	Potellostium montfortanum	Girty 20, 1	BPA
Gastropods	Pharkidonotus (Bellerophon)		
Gastropods	" percarinatus	Girty 19, 4	BPA
Gastropods	Bellerophon stevansanus	McChesney	A
Gastropods	Bucanopsis marcouana	Grabau 840	Br
Gastropods	Plagioglypta (Dentalium) meekiana	Girty 25, 14	Br
Gastropods	Sphaerodoma (Soleniscus)		
Gastropods	" ventricosus	Girty 24, 4	A
Gastropods	" " paludiniformis	Girty 24, 5	A
Gastropods	" " primogenia	Girty 24, 13	Br
Gastropods	" " texana	Shumard	A
Gastropods	Loxonema plicatum	Whitfield 11, 14	A
Chitons	Glaphurochiton carboniferus	Raymond 5, 4	PA
Cephalopods	Orthoceras rushense	Grabau 1254b	BPA
Cephalopods	" lasellense	Worthen	P
Cephalopods	Cyrtoceras curtum	Raymond 4, 3	Br
Cephalopods	Temnocheilus crassus	Hyatt	BPA
Cephalopods	T. winslowi	Grabau 1320a	PA
Cephalopods	Solenocheilus collectus	Grabau 1328	Br
Cephalopods	Tainoceras occidentale	Raymond 6, 7	ABi
Cephalopods	Goniotites lunatus	Smith 6, 2	PB
Trilobites	Griffithides scitula	Grabau 1616c	PB
Fishes	Petalodus ohioensis	Raymond 5, 9	BPA
Fishes	Deltodus angularis	Newberry & Worthen	BPA
Fishes	" compressus	Newberry	W
Fishes	Fissodus inæqualis	St. John & Worthen	A
Fishes	Cladodus occidentalis	Leidy	A
Fishes	Agassizodus variabilis	Newberry & Worthen	A
Amphibian	Eryops sp?	Case	R
Reptiles	Desmatodon hollandi	Case	R
Reptiles	Naosaurus raymondi	Case	R
Reptiles	Diadectid gen.? sp.?	Case	R

LEGEND.

B or Br = Brush Creek limestone.
P = Pine Creek limestone.
W = Woods Run limestone.
A = Ames limestone.
Bi = Upper limy bed of Birmingham shale.
R = Red beds near Pitcairn, Pa.

BIBLIOGRAPHY UPON WHICH THE FOREGOING LIST IS BASED.

Girty, G. H. *Fauna of the Wewoka formation.* U. S. Geol. Survey, Bull. 544.

Schuchert, C. *Text Book of Geology.* (Historical.)

Grabau and Shimer. *North American Index Fossils.* Figs. 1–2010, in Vol. I; others in Vol. II.

Case, E. C. Annals Carnegie Museum, Vol. IV.

Condit, D. D. *The Conemaugh Formation.* Geol. Survey of Ohio, Fourth Series, Bull. 17.

Raymond, Percy E. Annals Carnegie Museum, Vol. VII.

Norwood and Pratten. Proc. Acad. Nat. Sci., Phila., Ser. 2, Vol. 3.

Meek. U. S. Geol. Survey, Nebraska, Final Report.

Worthen. Geol. Survey of Ill., Vol. 5.

Whitfield. Geol. Survey of Ohio, Vol. 7.

Smith, J. P. *Carboniferous Ammonoids.* U. S. Geol. Survey, Monograph 42.

Plant Remains.

The fossil plants to be found in the Pittsburgh region are not so definitely limited to certain layers of rocks or "horizons," as the fossil animals. We usually find the most perfect specimens in black shales often underlying a coal-bed, but we may encounter some of the harder trees and branches as fossils in sandstone, or even in conglomerate. This kind of material within the limits of the city is generally poor in quality and specimens are not nearly as abundant as they are in association with the Allegheny coals to the north or to the east; nor can it be compared with the material to be found in the anthracite regions in northeastern Pennsylvania. Occasionally, however, one finds a good specimen, or a specially good locality, and it is well to be familiar with a few of the more common types of plants, which flourished in Conemaugh times.

We may expect to find specimens of various types of fern-like plants. These we can all recognize, even if we may not be able to place them in their proper genus or species. Most of them, it is now believed, were not true ferns, but belonged to a group of tree-like plants, which represented a transition between the true ferns and the Cycads. This transitional group differed from the true ferns in bearing seeds in place of the sporangia which are seen on the under side of the leaves of ferns. Both ferns and seed-ferns grew to immense size, often rising to over forty feet in height.

Fragments of the trunk or branches of two of the larger trees of the Carboniferous are occasionally encountered and are not hard to distinguish. They are *Lepidodendron* (Pl. VII, fig. 2) and *Sigillaria* (Pl. VII, figs. 4–6) both belonging to the family of Club-mosses or Lycapods, the living members of which are now lowly moss-like plants, the best known being the Ground-pine.

The trunk of *Lepidodendron* is easily recognized on account of the diamond-shaped leaf-scars left upon it as the leaves fell. These are not arranged in vertical rows, but alternately, so as to show an almost spiral arrangement. This tree reached a height of over one hundred feet with a diameter of two or three feet, the tall slender trunk branching toward the top, the branches covered with closely spaced needle-like leaves. The branches were terminated by cones. The petrified trunks have often been reported by coal-miners as "fossil snakes." *Sigillaria* (Pl. VII, figs. 4–6) differs from *Lepidodendron* in the markings upon the trunk. The surface is vertically grooved, or fluted, and each ridge carries a vertical row of leaf-scars. The tree was tall and unbranched, terminated by a head or cluster of long needle-like leaves, often three feet long, and also bearing cones. Specimens of these two trunks are almost invariably flattened on account of the fact that their interior was soft and cellular, easily decaying, thus allowing pressure to cause the stems to collapse. These are the two trees which enter most frequently into the make-up of coal-beds and their flattened trunks are often found in the "roof-slates," while microscopic investigation proves that the brighter layers in bituminous coal are flattened stems and trunks, and that spores from the cones, although flattened, make up a considerable portion of most coals. The roots of the Lycopods frequently are found in the under clays of a coal-seam and are termed *Stigmaria* (Pl. VII, fig. 1).

Another type of stem, or trunk, which is likely to be found is that of *Calamites*, which is vertically ribbed and jointed, somewhat like bamboo. *Calamites* (Pl. VII, fig. 7) was the giant ancestor of the roadside Horsetail- or Scouring Rush, and those who know this plant can see a close resemblance. The ancestral variety differed in size, being often sixty feet in height. It bore cones which carried spores. The stems, when found in sandstones, may be very little crushed.

Another large tree of the period was *Cordaites* (Pl. VII, fig. 8). This tree was most advanced along the lines of evolution of any of the trees of the period, and was related to the conifers of the present day, and possibly to the Japanese Gingko tree, so popular as a shade-tree in many of our parks. *Cordaites* bore both male and female catkins and developed winged seeds *Rhabdocarpos* (Pl. VII, fig. 3). The leaves borne on the upper branches were long and vertically ribbed resembling those of the lily, or Indian corn, and the leaves are the portions most frequently found.

Summarizing, the fossil plants most commonly found in our district are the fronds of ferns and seed-ferns, the trunk and stem of *Lepidodendron*, *Sigillaria*, and *Calamites*, and the leaves and sometimes the fruit of *Cordaites*. Other parts of these plants, especially the fruit, cones, spores, needles, as well as some less common plants, cannot be identified except by the paleobotanist, who devotes his time exclusively to the study of fossil plants.

There has been but little detailed work upon the fossil flora of the Conemaugh, or, in fact, but little upon any of the rocks of our region. The life in the roof-shales of the Pittsburgh coal was made the subject of a special investigation by Grier (Annals Carnegie Museum, Vol. IX, 1914, pp. 125–128). He gives a list of twenty-six species which have been identified, the material coming from the first cut on the Wilkinsburg-Ardmore Boulevard near the trolley stop at Bryn Mawr. His list includes:

Hysterites Cordaitis	a fungus	
Calamites	4 species	trees
Annularia	2 species	trees
Sphenophyllum	3 species	trees
Sigillaria camptotænia		
Pecopteris	2 species	(ferns)
Callipteridium	1 species	"
Neuropteris	5 species	"
Cordaites	5 species	
Rhabdocarpos mansfeildi		(a fruit)
Radicites or Pinnularia		(a root)

There are no doubt many localities, where even better material could be obtained, but no one has taken up the work.

The shales accompanying the Allegheny coals yield much better material. For example, the shales under the upper Kittanning coal at Darlington, yield one hundred and one species within a few yards.

An extremely interesting phase of the study of Carboniferous plant-life has been brought out by the painstaking research of Dr. Thiessen of the United States Bureau of Mines in his laboratory on Forbes Street. Dr. Thiessen for some years has been grinding extremely thin sections (one five-thousandth of an inch in thickness) of various coals, and has been examining their structure under high power microscopes. He finds that the lustrous layers show a woody texture and were once the branches or trunks of trees, now much flattened. The duller layers in the coal he finds to consist of the debris of plants, composed of fragments of leaf cuticle, pollen grains, spores, resinous particles, etc. Of this material the spores have proved the most interesting, for although less than one-thousandth of an inch in diameter and flattened, the spores have definite characteristic features, which make it possible to classify them. He finds that certain characteristic spores are found in the Pittsburgh coal-beds, and that through them he may identify this particular coal and differentiate it from the Freeport coal, or the Sewickley coal, or any other coal. In other words, the fine dust-like spores floating down from the trees, although so minute and seemingly fragile, have been preserved in the peat and in the coal for many millions of years, and that they are still so perfect that by their shapes and markings they become of actual value in the correlation and identification of coal-beds. Dr. Thiessen's important papers are cited in the Bibliography.

CHAPTER VI.

USEFUL MINERALS OF THE PITTSBURGH REGION.

To the mineralogist, hunting for beautiful specimens, or to the prospector, searching for gold or silver, western Pennsylvania is a barren district; for such minerals are not likely to occur among undisturbed sandstones and shales.

Nevertheless, we have extremely valuable mineral deposits, though not of the spectacular type. The value of the bituminous coal produced in Pennsylvania in 1922 was $351,777,000, of which Allegheny County furnished $35,726,000, while the entire production of gold in the United States was only $47,696,900. Pennsylvania ranks first among the states in the production of coal, clay-products, natural gas, and cement. In the production of the first three Allegheny County is of great importance. In the vicinity of Pittsburgh there are produced important quantities of coal, natural gas, petroleum, limestone, sandstone, gravel, sand, brick- and fire-clays, and portland cement, while until recently salt was also produced.

The coal mined in the Pittsburgh region is mainly from the Pittsburgh seam and it is considered to be one of the very best bituminous coals on the market. In emphasizing its importance H. A. Kuhn (Trans. Amer. Inst. Min. Engineers, Oct., 1914, p. 2587) says: "The Pittsburgh Coal Field in western Pennsylvania is conceded to be the most important in the world. To measure its importance it is necessary to understand the extent of its service in the various industries of the country. Probably 90 per cent. of the pig-iron manufactured in the United States up to the present time has been made by using coke manufactured from the Pittsburgh coal-seam in western Pennsylvania. This coal-field is the foundation on which the city of Pittsburgh rests and is the reason for the great growth of the iron industry in the Pittsburgh district. Iron ore is brought to this district, not because Pittsburgh is a natural location over other locations for the iron and steel industry, but the ore is brought eleven hundred miles to meet the fuel. It can be said that the illuminating-gas industry in the United States has used this coal exclusively to the same extent that the pig-iron maker has used it. It may be also said that 20 to 25 per cent. of the fuel used on railroads in the United States comes from this coal-field. The Pittsburgh Coal-field is unquestionably the center of the industrial population of the United States, for in addition to the industries of the district and those closely adjoining, it has tributary to it all the cities and industries along the Great Lakes and practically all of Canada, with the exception of the extreme western and eastern ends. It supplies the industries and population west of Duluth and Superior many hundreds of miles. This coal is floated down the Ohio and Mississippi rivers, supplying the towns en route, and is delivered in New Orleans, a distance of twenty-two hundred miles, for approximately eighty to ninety cents per ton transportation cost. It is delivered on the docks of Superior and Duluth at a cost of transportation fifty cents a ton less than the cost of transporting the same coal from Pittsburgh to a local consumer in Philadelphia. With other Appalachian coals it has large markets east and along the sea-board, especially for byproduct-coke making and the illuminating gas industry. It is considered the premier railroad fuel of the world on account of the fact that this coal in a given-size locomotive will probably haul more cars than any other coal in the world. Tests made at Altoona by the Motive-power Dept. of the Pennsylvania Railroad Co. show that Pittsburgh gas-coal evaporates as high as 18.9 lb. of water per square foot of heating surface. It is stated that the lower volatile coals, with a theoretically higher heat value per pound of fuel, do not evaporate more than 12 to 13 lb. of water per square foot of heating surface. For this reason this important railroad has adopted this coal as its standard fuel. By its use with the same crew and engine a maximum number of cars may be hauled."

It retains a uniform thickness over large areas and outcrops in our region in such a position along the river banks that it can be easily loaded into barges or railroad cars. It lies, as do all of our strata, practically horizontally, so that from the hillside it can be mined by direct drifts or tunnels. In Pittsburgh itself the coal lies at an approximate elevation of one thousand and fifty feet above sea-level with some slight variations, and therefore is found only near the tops of the higher hills, its outcrop circling around the hill. It outcrops in Schenley Park, in Squirrel Hill, around Herron Hill, and in the early days was mined in some of these city districts. To the south, southeast, and southwest its downward dip carries it to much deeper levels and in the Connellsville district it reaches river-level. On account of the lesser amount carried away by erosion, the coal at the lower levels is a more continuous body; under Greene and Washington County the bed is one continuous sheet although lying deep beneath the surface. The rise to the north carries the Pittsburgh bed so high in northern Allegheny County that it is found only on a few high knobs, the most northern exposures being certain very small hills in Pine Township.

Although seemingly horizontal, the bed, like all of our strata, shows evidence of the Appalachian folding and careful measurements with the aneroid barometer or a surveyor's level show that the coal lies in low waves, the crests of which are called the axes of anticlines. These axes of the folds run in a northeast southwesterly direction, and the coal dips from them in a southeast or northwesterly direction. The axes are not straight, nor are the dips regular, so that it is necessary in detailed mapping of a coal district to make many measurements of the altitude of the coal-bed and then to construct a map along the lines of a topographic map only drawing the contours or lines of equal elevation with reference to the coal-bed. Such a map is termed a structural contour map and indicates to the trained eye just how the entire coal-bed lies. The Carnegie quadrangle has been worked out in this way and its anticlinal axes and synclinal axes (the axes of the troughs of the folds) are indicated on the structural map. In connection with this work there has been discovered a most curious irregularity in the bed between Beadling and Hickman. There the coal occupies a steep, narrow trough or "trench," running from east to west, known as the "Panhandle trench." The coal throughout the region has a very slight dip, dips of two degrees or one hundred and eighty-four feet to a mile being rare. In this small area, however, the bed plunges into a trough depressed forty feet, with its sides sloping at eleven degrees. The coal in the trench is thicker than that at the sides and it is believed that the trench is an original depression in the swamp, or bog, in which the coal was formed.

To the north of Pittsburgh, the Freeport coal is mined at Creighton, Valley Camp, and other localities on the Allegheny River; while farther north on the Allegheny the Kittanning coals play an important part. On the Ohio River in the Beaver region the lower Kittanning and Upper Freeport coals are of the greatest importance.

Building Stone. The only stone of any value for building purposes is the coarse sandstone. It is quarried mostly from the Morgantown stratum, which is often massive in character. This stone is a bluish or light gray stone carrying considerable mica in shining scales and also some decomposed grains of feldspar which under a lens appear as soft white specks. The main disadvantage of our local stone is its very irregular jointing and bedding. This makes it impossible to attempt to use it in dressed rectangular blocks and it is quarried and used generally in rough, irregular pieces. These, however, when laid by an experienced mason, may be made very attractive, and have been used to good effect in many churches and like buildings. The chief use of the local stone, however, is for foundations, retaining walls, and similar structures. Throughout the city and its suburbs quarries have been opened in many places, the attempt usually being made to quarry into a hill-side. Many of the quarries are planned so as to utilize the overlying clay, or shale, in the manufacture of brick, so that the firm-name is often that of a "Brick and Stone Company."

The Mahoning sandstones in northern Allegheny county and beyond are much more massive and furnish a better grade of stone under the name of "Beaver" or "Beaver Valley" stone. It is yellowish in color, has almost a sugary texture, and generally carries less mica and clayey impurities than our strictly local stone. Many smaller buildings, especially churches, are constructed of this stone. As with the local stone, its irregular jointing makes it necessary to use it in the form of rough blocks. Buildings such as the Masonic Temple, the Pittsburgh Athletic Club, the Carnegie Library and the Armory of the Eighteenth Regiment are built of stone imported from outside the state, the two former being faced with Indiana Limestone, and the two latter with Ohio Sandstone. Many of our more expensive buildings are faced with granite which is mainly brought from the New England States.

Clay and Shale. Clay and shale-beds of the Conemaugh and the Lower Monongahela formations are extensively quarried within the city limits for the manufacture of clay-products, and there are many large plants which turn out brick, fire-proofing material, and other minor products.

The beds used range in position from such as at Sharpsburg, which lie just above and below the Ames limestone, to others on Herron Hill, which lie above the Pittsburgh coal. They vary from almost pure clay shales to sandy shales or to shales carrying many limestone nodules. A proper product can only be obtained in most yards by a careful mixture of material from several beds or benches. At times even some of the overlying yellowish sandy soil or stripping is employed. Each brick-yard is thus a problem in itself. The shale is dug by hand, or by steam-shovel, and usually conveyed to the plant in some type of small car on a track. In the plant it is crushed to a fine state with the use of a dry-pan, a horizontal wheel like a millstone, around which travel two large wide vertical wheels on an axle crushing the shale as it is fed under them. If the clay carries nodules of limestone they are sorted out by hand during quarrying, or screened out before crushing, for lime pebbles in the burned brick are one of the worst things a Pittsburgh brick-maker must face. The limestone during the burning changes to quick-lime and after the brick are burned a little moisture swells these lumps and the brick disintegrates. After grinding, the clay is carried into a pug-mill, a horizontal chamber where water is added and the mass thoroughly kneaded by revolving paddles. The plastic mass is then pushed on by a screw-like propeller and soon issues from a rectangular steel die in a plastic stream like the tooth paste which "lies flat on the brush." This bar of soft clay is then automatically cut into proper sizes by a series of wires revolving on a frame work. The "green" bricks are placed on cars and sent into steam-heated drying rooms, whence, when dry, they are taken to the kilns where they are loosely stacked. The fires of the kiln are lighted; the moisture of the clay passes off; and, as the heat is raised, the bricks shrink, harden, and take on a bright red color. With some variation this process is taking place in most of the brick-yards of the city. With the use of a different die hollow brick, fireproofing, or drain-tiles may be made in place of common brick. A trip to one of the larger yards is interesting.

Although many fire-bricks are made in the city, the clays used are all brought in from without the county, mainly from Clarion and Clearfield Counties. In a trip to the Beaver Valley or to the Kittanning district one may also witness the mining of fire-clays. These clays generally lie in thin beds under a coal-bed (in the Beaver region under the Lower Kittanning coal) and are mined as coal is mined. Fire-clay differs from our brick-clays in containing less fusible elements, such as oxide of iron or calcium (lime), and therefore withstands much higher temperature. On account of its lack of iron it generally burns white or yellowish, and many of our buildings are built of light-colored brick made from the fire-clays of the Kittanning district. The high grade fire-clays of Western Pennsylvania and the shales suitable for brick, tile, paving brick, and terracotta are of great importance and the production in the region is enormous. A little further west at East Liverpool, Ohio, the presence of fine clays has resulted in the establishment of great potteries.

Sand and Gravel. The production of sand and gravel in Allegheny county is surprising. We produce more than any other county in the United States and more than most of the other states. Most of this is obtained from the lower terraces of the Ohio and Allegheny rivers, by dredging in the rivers, or from similar deposits on the banks of the Monongahela River.

As explained in Chapter IV, the sand and gravel of the Allegheny and Ohio is of glacial origin and carries harder pebbles and sharper grains of sand than that of the Monongahela, the sands of which are derived from the breaking down of shales and sandstones of local origin. The Allegheny sands are therefore much more abundant and considered to be superior in quality. Both the lower and the higher glacial terraces are worked, the lower being generally better preserved and more accessible. The higher terrace is extensively worked on Woodlawn Avenue, Allegheny, where fifteen feet of good sand and gravel underlie ten feet of poorer material, which is stripped away.

Dredging is the method which furnishes the larger part of our gravels. Of this method E. W. Shaw says: "In dredging, a favorable spot is chosen, where the gravel is loose and of desirable quality. The material is brought up by bucket endless chains and is screened and washed with one handling. Gravel is usually loaded on barges on one side of the dredge, while sand is loaded on the other. Several different sizes of gravel are produced. A 3-inch-mesh screen is used for general heavy concrete gravel; 1½ inch for material for sidewalks and small reinforced concrete. Frequently ¾ inch gravel also is screened out. The average amount of gravel and sand obtained in the material worked is variously estimated at 15 to 30 per cent. It is often said that the boulders and fine waste occupy as much space as the original deposit. In ordinary stages of the river, dredging operations are carried on more extensively on the Allegheny, but in times of low water the gravel is taken from pool No. 1 on the Ohio. A small amount is taken every year from the Monongahela, but the sand and gravel of this stream are of so much lower value that the deposits are not worked extensively." (U. S. G. S., Bull. 430, p. 395, 1910.) Mr. Shaw goes on to say that the river is constantly replenishing the depleted supply or uncovering new beds and the supply is thus maintained although dredging for local markets is constantly pushing farther and farther away from the city.

The sand in addition to its use in building is used in smaller amounts for molding, glass grinding, filtration beds, furnace bottoms, paving, etc.

Limestone. The limestones of the city proper are practically valueless. Occasionally in a shale quarry the thin layers and blocks of limestone are gathered and used as flux in small iron foundries, but the layers are too thin to be worth quarrying. In the country districts a thin layer of such limestone is sometimes quarried by the farmer and crudely burned to furnish him with lime for improving his soil. Farther from the city, as in Washington County, some of the fresh-water limestones above the Pittsburgh coal attain a greater thickness, and not only are utilized in burning lime, but themselves directly enrich the soil giving Washington County a reputation as a farming district. They are generally too high in magnesia to be of value in the manufacture of Portland cement.

North of the city in Lawrence County the thicker Vanport limestone comes in and is used in making lime. At Newcastle and Wampum it is mixed with shale and burned at high temperature to form Portland cement. Portland cement is also made east of Pittsburgh at Universal on the Bessemer & Lake Erie Railroad, but no local rock is used, the limestone coming from central Pennsylvania and blast-furnace slag being used in place of shale.

The enormous amounts of limestone used as a "flux" to assist in the smelting of the iron ores in Pittsburgh's furnaces comes from the mountains of central Pennsylvania and from the Vanport limestone north of us.

Our paving blocks are also made of a hard siliceous limestone which is quarried from what is known as the Loyalhanna limestone of Mississippian age, the quarries being situated at the Loyalhanna Gap near Latrobe, on the Conemaugh river near Blairsville and elsewhere. This stone is known as "Ligonier Block."

OIL AND GAS.

Surrounded, as we are, with oil- and gas-wells and supplied so abundantly with gas for fuel and light, yet there are many who have but a faint conception of, or often erroneous ideas concerning, the mode of occurrence of these valuable hydrocarbons.

One erroneous idea held by many is that the oil or gas lies in huge open reservoirs or underground lakes, this same idea being held in some regions in regard to underground water-supplies. In the case of oil or gas the term "pool" is indeed used, but it refers simply to an area from which oil or gas may be extracted. The "pools" are simply porous strata, or parts of a stratum, which are saturated with oil or gas under pressure. Any porous rock might serve as container, but in most regions sandstone serves as the best. In our own district the hydrocarbons are invariably found in the porous sandstones.

These oil- or gas-bearing sandstones are known among drillers as "sands," another term which might mislead, for the rock is not an unconsolidated sand, but a hard sandstone, very much the same as the sandstones outcropping in our city. In fact, the Morgantown sandstone farther south, where it lies at a distance from the surface, is often oil-bearing and becomes known as the "Murphy sand." The driller has a name for each important sand and knows the approximate intervals between them, and also recognizes certain other important marking horizons such as the Pittsburgh coal, certain red shales, etc. These, with the aid of the records of nearby wells, make it possible for him to know at what depths he may expect the various "sands".

The following table largely taken from Clapp (Economic Geology, Vol. VIII, 1913, p. 520) gives the names of the various sands, the equivalent sandstones for some of them, their geologic formation, and their approximate depth below the Pittsburgh coal, although this naturally shows considerable variation.

Name of "sand"	Name of sandstone	Formation	Depth below Pittsburgh coal in feet
Murphy	Morgantown	Conemaugh	200
Little Dunkard	Saltsburg	"	350
Hurry Up	Mahoning	"	400
Second Cow Run	Freeport	Allegheny	650
Gas		"	750
Johnson Run	Homewood	Pottsville	900
Upper Salt	Upper Connoquenessing	"	950
Middle Salt	Lower Connoquenessing	"	1050
Lower Salt	Sharon Conglomerate	"	1130
Big Injun	Sub Olean	Pocono	1350
Upper Gas		Catskill	1550
Butler Gas	Berea	"	1750
Murraysville		"	1800
First, Gantz, or Hundred Foot		"	1850
Fifty foot		"	1900
Second, or Nineveh		"	2000
Boulder, or Gordon Stray		"	2070
Third, or Gordon		"	2130
Fourth		"	2200
Fifth		"	2250
Bayard		"	2400
Sixth		Chemung	2600
Warren first		"	2700
Warren second		"	2800
Tiona		"	2900
Speechley		"	3000
Balltown		"	3120
Sheffield		"	3220
Bradford		"	3430
Second Bradford		"	3480
Elk		"	3650
Kane		"	3770

In the territory immediately surrounding Pittsburgh the wells generally range from 1200 to 2800 feet in depth and pass through the sands down to the Fifth, which lies near the bottom of the Catskill formation of the Upper Devonian. The largest amount of oil has been taken from the lower sands from the Gantz to the Fifth. Farther to the north, on account of the general rise in the strata, the sands of the Chemung formation are drilled.

Unfortunately for those who seek supplies of oil or gas, the entire sand is not impregnated with the hydrocarbons. Some portions are "dry," others filled with salt water, and only irregular areas contain the oil or gas.

It is today agreed almost without question among geologists that the crude petroleum and natural gas have originated through some peculiar form of decomposition or distillation from animal or plant remains entombed in the mud and sand during the formation of the sedimentary rocks. That which originally was formed in the muds (now shales) has subsequently migrated into the more porous sandstones. The causes of this migration, subsequent movements through the sandstones, and the final collection into "pools" of oil or gas under pressure, must be understood before real scientific exploration of oil- or gas-fields can be undertaken. These problems of accumulation have been and still are the source of much discussion, and the science of oil geology is as yet in its infancy.

The theory held by most geologists is what is known as the anticlinal or the structural theory. As originally propounded, this theory was, that the hydrocarbons were collected under anticlines in a porous stratum overlain or capped by impervious layers. By reason of their difference in specific gravity, oil, gas, and salt water present in the pores of the sandstone tended to separate; the gas, being lightest, rising to the summit of the anticline or dome; the oil being below on either flank, and the salt water resting still lower on the flanks or in the neighboring syncline. The varying amounts of each constituent determined the extent of each zone. If no salt water was present, the oil would lie in the syncline.

This simple method of accumulation is seldom encountered in nature, for we find, that, although the oil- and gas-pools are seemingly related to anticlinal structure, this structure is irregular and complex; that the accumulation may be hampered by the density of certain portions of the strata and by its lenticular character; or that the presence or absence of water has played a part in the accumulation greater than is assumed in the original theory. We also find that the oil may occur in beds of monoclinal dip, i. e., beds tilted in one direction, if certain lenses are more porous than the rest, or that it may occur on terraces or areas of arrested dip or change in dip, all of which are but modifications of the original theory.

The individual pools present many unsolved problems, exceptions to the general rule being so common, as to almost seem to demand an altogether different theory. Nevertheless, as a working hypothesis the relation of oil and gas to structure still stands, and the oil geologist must search out the anticlines and domes before drilling can be intelligently carried on.

One drawback to the solution of the problems was eliminated when it was realized that the strata at depths were not necessarily parallel to surface structures, and that, for instance, the Fifth Sand from which oil was being extracted might show anticlines not indicated in the Pittsburgh Coal at the surface. The careful compilation of numerous records of wells makes it possible to work out the real structural irregularities of a deep sand and map the same by the use of the contour method. The underground contours of the more important oil-sands are now generally shown on maps of oil and gas regions. The oil- and gas-belt crosses the western part of the state in a northeast to southwest direction, paralleling the axes of folding. The oil-pools lie in the less folded western portion west of Pittsburgh, while the gas-fields extend into more highly folded strata beyond Greensburg. Pittsburgh thus lies just east of the main oil-belt, important oil-fields lying west, northwest, and north.

To the west lie the important oil-fields of the Carnegie and Burgettstown quadrangle. In these two quadrangles there are sixty-four square miles of territory underlain by proven oil-pools. Of these the McDonald field is one of the largest in the State, being twelve miles long and from one to three miles wide. Active drilling began in 1890–1891, and oil was first found in the Gordon Sand, later in the Fifth Sand. Wells produced as high as 10,000 barrels of oil per day and excitement ran high. By 1892, eight millions of barrels of oil were flowing yearly, but this was the year of highest production. After the manner of all oil-pools the flow steadily decreased from then on, until today, though still an important field, it yields only about half a million barrels.

Nearer the city lie the Chartiers-field, back of McKees Rocks, and the Bellevue-field practically abandoned. The Sewickley quadrangle to the northwest of Pittsburgh is another large oil and gas region. Within its borders are some ninety pools varying from a few acres to several square miles in extent. Although they have long since passed the maximum of their production, many of the pools are still good producers, and oil and gas are the principal mineral products obtained in the quadrangle. Some of the pools nearer the city, such as Coraopolis, Neville Island, Mt. Nebo, and Wildwood derive oil from the

Gordon Sand, but the larger pools to the north pump from the Hundred Foot Sand.

With the oil-pools in both these oil regions are many gas-pools. In addition much gas is obtained in large pools east of Pittsburgh. Within the city quite a number of isolated wells have been drilled and are now flowing, but the enormous supply needed for such a large city is drawn through pipe-lines from long distances, some even from West Virginia. Like the oil, gas-production is diminishing yearly, and supplies must be drawn from more distant sources every year.

The great excitement over the McKeesport gas-field in 1920 and 1921 was the result of the drilling of a gas-well in the Speechley Sand, which well at first produced 55,000,000 cubic feet of gas per day, making it the largest and best paying gas-well ever drilled. Unfortunately, the speculative fever which followed resulted in the drilling of over six hundred wells within an area of not much over a square mile, a very sudden drop in gas pressure, and in the rapid draining of the field. Out of six hundred, or more, wells drilled, four hundred and twenty-nine were "dry holes" and the production in many others was slight. Between the honest but unintelligent projects and the unscrupulous promoter some $20,000,000 were expended, and the return in gas amounted to $2,000,000. A few wells, intelligently placed, could have drained the field with a slow gradual production, given it a longer life, and yielded a good return for the money expended.

An interesting oil-pool has recently been discovered near Corliss Station and Sheridan, which is within the city limits. This field was opened in the summer of 1922 and on September 21, four wells were producing from ten to one hundred barrels each per day, and more wells were being drilled. This oil comes from the "Hundred-foot Sand", which lies at a depth of about seventeen hundred feet.

Some of the old reports of the Second Geological Survey, such as the Annual Report for 1886, Part II, give fascinating information about the early search for oil and gas in or near Pittsburgh. In 1845 Mr. Lewis Peterson of Tarentum brought petroleum to Pittsburgh, the oil having come up in his salt wells and given him considerable trouble. The managers of the Hope Cotton Factory mixed it with sperm oil and used it for the first time as a lubricant. A few years later, Samuel M. Kier obtained similar oil from his salt-wells at Tarentum and sold it at 50 cents a bottle as "Kier's Petroleum or

Rock Oil, Celebrated for its wonderful curative powers." From Kier's circulars and from knowledge of oil-springs both in New York and Pennsylvania, men conceived the idea of drilling for oil at Titusville, Pa., and in 1859 the first oil well was drilled, the famous "Drake Well."

Natural gas was first used for lighting houses in Fredonia, New York, in 1821. The first company to pipe it and extensively use it to supply a large body of customers was organized in Titusville, Pennsylvania, in 1872. Mr. J. N. Pew was a leader in this enterprise. It is said to have been first used for iron-making at Leechburg in 1874. In 1875 Messrs. Spang, Chalfant, and Company began to employ it in their puddling furnaces at Etna in the suburbs of Pittsburgh. They drew their supplies from wells located in the Butler field. Their success led the owners of the Black Diamond Steel Works, Mr. James M. Park and his partners, and of the Kensington Iron Works, Messrs. Henry Lloyd and Sons to drill at their works, but they only obtained a flow of salt water and desisted. On January 19, 1882, the Fuel Gas Company was incorporated by Mr. Sellers McKee and associates, and shortly afterwards the Penn Fuel Company controlled by the Pew interests was also incorporated. These two companies, drawing their supplies of gas mainly from the Murraysville field, undertook to provide natural gas in Pittsburgh under the general law provided for artificial gas companies, and each of the companies claimed a monopoly in the city. The Supreme Court ruled that neither company was entitled to operate under the general law controlling the distribution of artificial gas. This subsequently resulted in the year 1885 in the passage by the legislature of Pennsylvania of a general "Natural Gas Act." The first successful effort to sink a gas-well in the immediate vicinity of Pittsburgh was made by Messrs. Brace Brothers in Wilkinsburg, to supply fuel for their laundry. It was quickly followed in Pittsburgh by the Westinghouse well drilled in 1884 by Mr. George Westinghouse, Jr., for the original purpose of obtaining fuel for his hot-houses and conservatory. This well proved to be a "roarer." The noise of its discharge could be heard for more than a mile, and when it accidentally took fire the huge flame lit up the whole East Liberty valley. The discovery of such a supply of gas near at hand led Mr. Westinghouse to obtain an ordinance enacted by the Councils of Pittsburgh on July 21, 1884, giving him the right to sell gas within the city limits. This ordinance Mr. Westinghouse soon transferred to the Philadelphia Company. Shortly thereafter various other companies were formed and were ultimately consolidated until today the great municipality at the headwaters of the Ohio derives the chief portion of its supply through the Philadelphia Company which perpetuates the memory of Mr. Westinghouse and his friends, and the Peoples Gas Company representing the consolidation of the interests of Mr. Pew and others. By 1885 thirty wells had been drilled in Pittsburgh, forty in the outlying districts of Allegheny County, and seventeen in the Murraysville district.

IRON ORES.

At the present time no iron ore is being mined in western Pennsylvania, and the industry may probably never be revived. Ore of better quality and in enormous quantity occurs in the Lake Superior region, and all of the ore used in Pittsburgh comes from that region. From an historical standpoint, however, the iron-ores of western Pennsylvania are interesting, for, from the building of a furnace at Fairchance in 1792 the iron industry expanded until furnaces were scattered all over the western counties and the mining of iron-ore was a serious industry. Taking up any of the old reports and reading of the number of charcoal furnaces using these ores and the "enormous" deposits, the comparison with today makes one almost smile. The charcoal furnaces were built near the ore, often in inaccessible places, but gave way in time to coke-furnaces along the railroads, and these in time began mixing ore from the lakes and native ore, until finally the use of native ore was abandoned. Our native ores are thus responsible for the growth and development of this great iron-working center.

The ore occurs as nodules in the shales, the nodules consisting of siderite, or limonite, with occasionally some hematite. Under the Pittsburgh Coal in the city we may often find round heavy nodules like cannon balls, sometimes with rusty surfaces, sometimes bluish-gray. These are nodules of siderite, or carbonate of iron, or clayey-iron-stone. They are tough and hard to break, and within are grayish brown, and very dense, resembling a limestone, but much heavier. On exposure in a cliff they often become oxidized to yellowish brown limonite, or hydroxide of iron. They are supposed to have been deposited from swampy stagnant iron-bearing waters, carrying organic matter in sufficient quantity to prevent the precipitation of the iron in the commoner form, hydroxide of iron, or "bog ore."

These layers lie at various positions in the strata of western Pennsylvania, and, where thick enough, were formerly mined. The most important source of the native ore, however, was a layer of irregular nodular limonite and hematite which lies directly upon the Vanport or ferriferous limestone. It is generally less than one foot in thickness, but locally thickens to several feet. Many furnaces using this ore were established in Lawrence County, Cambria County, and elsewhere. The ore is generally believed to represent a concentration of iron oxides brought about by the solution of iron-bearing limestone layers upon which it lies. In its original form it was probably a carbonate mixed with the carbonate of lime of the limestone. All of these carbonate ores are low in iron, so much lower than the ore from the lakes, that there seems no possibility of their use, especially when one considers the cost of mining such thin deposits.

BIBLIOGRAPHY.

Information concerning the geology of the Pittsburgh region must be obtained chiefly from two sources. First, from the publications of the various geological surveys, which have been organized under state control and second from the publications of the United States Geological Survey.

Under State control there have been four organized geological surveys. The First Geological Survey was organized in 1836 with Professor H. D. Rogers as State Geologist. Annual reports were issued from 1836 to 1842 and two quarto volumes issued as a final report in 1858.

The Second Geological Survey was organized in 1874 and continued until 1887. An enormous amount of work was done by an enthusiastic group of men and as a result seventy-seven volumes, thirty-five atlases, and a Grand Atlas were published. After the lapse of a few years a final Summary appeared in 1893 to 1895 in three octavo volumes. The reports of this Second Survey are no longer available for distribution, but can often be obtained in second-hand bookstores, or can be found in most public libraries.

The Third Survey was organized in 1899 as the "Topographic and Geological Survey," under a commission with the late R. R. Hice of Beaver as State Geologist. This survey co-operated with the Federal Survey in the preparation of many topographic maps and folios and also issued many valuable reports and bulletins, of which the Report for 1906–1908 probably is the most valuable for general information.

The Fourth Survey organized was that of 1919 when a geological survey was established at Harrisburg under the Department of Internal affairs. Dr. George H. Ashley was appointed State Geologist. The Survey now has a competent staff of workers and is issuing important bulletins on the geology of the State.

The United States Geological Survey has issued many publications, which can be obtained either free or for a small charge, and these contain important data concerning the geology of the state. Especially important are the topographic sheets which have been completed for the greater part of the State and the geologic folios some of which are listed below. Lists of these maps, folios, and bulletins pertaining to the geology of Pennsylvania can be obtained from the Director in Washington, D. C.

A list of the more important references to the geology of Pittsburgh and western Pennsylvania follows:

Ashley, G. H. (and others) Pennsylvania Topographic and Geologic Survey Report for 1906–1910.

" (and J. F. Robinson) Oil and Gas Fields of Pa. Pennsylvania Geological Survey, 1922.

Boileau, J. W. Coal-Fields of Southwestern Pennsylvania, 1907.

Chamberlain, R. C. (and Leverett) Drainage Features of the upper Ohio Basin. Am. Jour. Sci., 1894, p. 147; p. 247.

Campbell, M. R. Geographic Development in Northern Pennsylvania and Southern New York. Bull. Geol. Soc. Am., XIV, 1903, p. 277.

" Masontown-Uniontown Folio. U. S. Geol. Survey, Folio 82, 1902.

" Brownsville-Connellsville Folio. U. S. Geol. Survey, Folio 94, 1903.

Case, E. C. Description of Vertebrate Fossils from the Vicinity of Pittsburgh. Annals Carnegie Museum, IV, 1908, p. 234.

Clapp, F. G. Limestones of Southwestern Pennsylvania. Bull. U. S. Geol. Survey, 1905, No. 249.

Cummins, A. Geology of the Natural Gas Fields about Pittsburgh. Eng. and Min. Journal, LIV, 1892, p. 106.

Condit, D. D. Conemaugh Formation in Ohio. Geol. Surv. of Ohio. Bull. 17, 1912.

D'Invilliers, E. V. The Pittsburgh Coal Region. Second Pa. Geol. Survey, Annual Reports for 1885 and 1886.

Foshay, P. M. Preglacial Drainage of Western Pennsylvania. Am. Journal Sci., XL., 1890, p. 397.

Grant, U. S. A Geological Excursion in the Pittsburgh Region. Bull. Geol. Soc. Am., XIV, 1903, p. 3.

Grier, N. M. A Preliminary List of the Fossil Plants Occurring in the Roof of the Pittsburgh coal. Annals Carnegie Museum, IX, 1914, pp. 125–128.

Griswold, W. T. Pittsburgh Coal in the Burgettstown Quadrangle. U. S. Geol. Survey, Bull. 260, 1905, p. 402.

Jillson, B. C. River Terraces in and near Pittsburgh. Trans. Acad. of Science and Art of Pittsburgh, 1893.

" Home Geology, 1890.

Lesley, J. P. Dictionary of Fossils, 2nd Pa. Geol. Survey, 1889, p. 4.

" Geological Hand-Atlas of the Sixty-seven Counties of Pennsylvania. 2nd Pa. Geol. Survey, Vol. X, 1885.

Lesquereux, L. Coal Flora of Pennsylvania and the United States. 2nd Pa. Geol. Survey, Vol. P., 3 Volumes and Atlas, 1879–1884.

Leverett, F. Glacial Formations and Drainage Features of the Erie and the Ohio Basins. U. S. Geol. Survey, Monograph 41, 1902.

Lewis, H. C. The Terminal Moraine Across Pennsylvania. 2nd Pa. Geol. Survey, Vol. Z, 1884.

Munn, M. J. Oil and Gas-fields of the Carnegie Quadrangle. U. S. Geol. Survey, Bull. 456, 1911.

" Sewickley Folio. U. S. Geol. Survey, Folio 176, 1911.

" (and E. W. Shaw) Burgettstown-Carnegie Folio. U. S. Geol. Survey, Folio 177, 1911.

Raymond, P. E. A Preliminary List of the Fauna of the Allegheny and Conemaugh Series in Western Pennsylvania. Annals Carnegie Museum, VII, 1910, pp. 144 *et seq.* Also in Pa. Top. and Geol. Survey for 1908–1910, 1911, p. 81.

" Some Sections of the Conemaugh Series between Pittsburgh and Latrobe. Annals Carnegie Museum, V, 1909, p. 166.

" Notice of Two New Horizons for Marine Fossils in Western Pennsylvania. Science, N. S., Vol. XXIX, 1909, p. 940.

" On the Discovery of Reptile Remains in the Pennsylvanian near Pittsburgh. Science, N. S., Vol. XXVI, 1907, p. 835.

Shaw, E. W. Sand and Gravel in the Pittsburgh District. U. S. Geol. Survey. Bull. 430, 1910, p. 388.

" Sketch of Local (Pittsburgh) Geology. Bull. Geol. Soc. Am., XXII, 1911, p. 271.

" High Terraces and Abandoned Valleys in Western Pennsylvania. Jour. Geol. XIX, 1911, p. 140.

Stevenson, J. J. First Report on Fayette, Westmoreland, and Southeastern Allegheny Counties. 2nd Pa. Geol. Survey, Vol. K2, 1877.

Thiessen, R. (and J. N. Stand) Correlation of Coal Beds of the Monongahela Formation, Bull. 9, Coal-mining investigation. Carnegie Institute of Tech., 1923.

" (and Wilson, F. E.) Correlation of Coal-Beds of the Allegheny For- Formation, Bull. 9, Coal Mining Investigation. Carnegie Institute of Tech., 1924.

Wall, J. S. Monongahela River Coal Mines. 2nd Pa. Geol. Survey, Vol. K4, 1884.
White, D. Description of the McDonald Well. Bull. Geol. Soc. Am., XXIX, 1918, p. 96.
White, I. C. The Geology of the Pittsburgh District. Abstract in Science, N. S., XVI, 1902, p. 258.
" Origin of the High Terrace Deposits of the Monongahela River. Am. Geologist, XVIII, 1896, p. 360.
" Beaver, Northwest Allegheny, and Southern Butler Counties. 2nd Pa. Geol. Survey, Vol. Q, 1878.
" Stratigraphy of the Bituminous Coal-fields in Pennsylvania, Ohio, West Virginia. U. S. Geol. Survey, Bull. 65, 1891, p. 212.
White, D. (and M. R. Campbell) The Bituminous Coal-field of Pennsylvania, U. S. Geol. Survey, 22nd Ann. Report, Pt. 3, 1902, pp. 127–200.
Williams, E. H. The Alleged Parker Channel. Bull. Geol. Soc. Am., XII, 1901, p. 463.
" Allegheny Valley Erosion. Science, N. S., XXXVII, 1913, p. 447.
Woolsey, L. H. The Beaver Folio. U. S. Geol. Survey, Folio 134, 1905.
" Economic Geology of the Beaver Quadrangle. U. S. Geol. Survey, Bull. 286, 1906.
Wright, G. F. The Glacial Boundary in Western Pennsylvania. U. S. Geol. Survey, Bull. 58, 1890. Also papers concerning the question of the Cincinnati Ice dam and the River Terraces in Volumes XI, XIII, and XVII of the American Geologist.